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Proceedings of the 1987 Prairie Federal–Provincial Nurserymen's Meeting

I.K. Edwards, compiler

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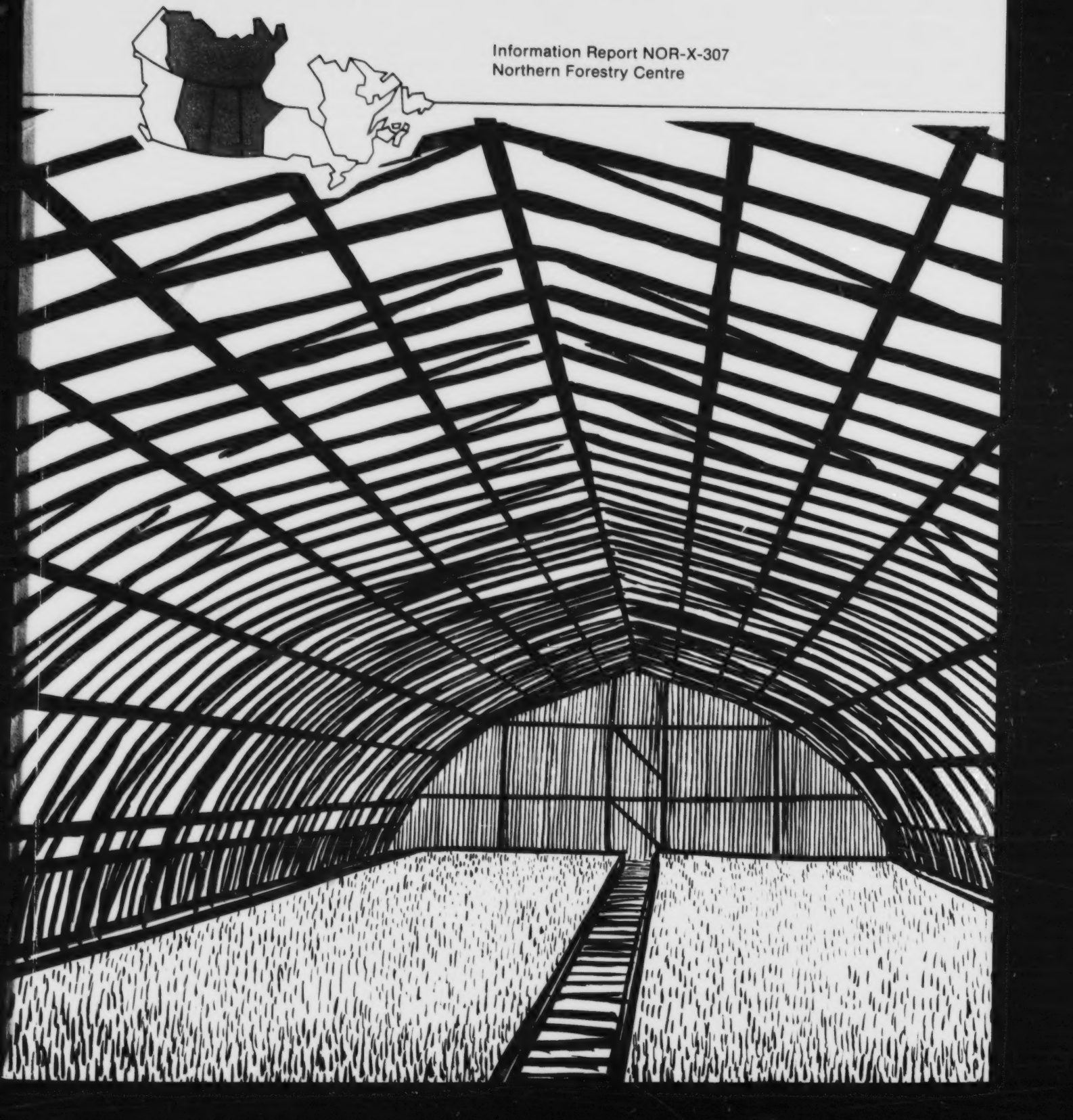

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PROCEEDINGS OF THE 1987 PRAIRIE FEDERAL-PROVINCIAL NURSERYMEN'S MEETING

September 8-10, 1987, in Indian Head, Saskatchewan

I.K. Edwards, compiler

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ABSTRACT

In 1987 the 13th Federal–Provincial Nurserymen's Meeting was held for prairie forest tree nursery personnel. Its purpose was to facilitate technology transfer between researchers and operational staff, exchange ideas, and solve production problems to enhance the quality of nursery stock. Papers were presented on seedling culture, vegetation management, and cold storage, three of the most important activities in prairie nursery operations. Production summaries from various nurseries are presented in a section on nursery operations. Research activities that were visited at the PFRA Shelterbelt Centre in Indian Head are described.

RESUME

En 1987 a eu lieu la 13 conférence fédérale–provinciale des pépinières forestières des Prairies. Son objectif était de faciliter les trans ferts technoigiques entre chercheurs et pépiniéristes, de favoriser les échanges d'idées et de trouver des solutions à des problèmes de production en vue d'améliorer la qualité des produits de pépinière. Des communications ont été présentées sur la culture des semis, l'amé nagement de la végétation et la conservation au froid, trois des plus importantes activités des pépinières des Prairies. Des données sur la production de diverses pépinières sont présentées.

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NOTE

This publication reports research involving pesticides. All pesticides are registered by Agriculture Canada for experimental use and have provincial approval before they can be applied. The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Forestry Canada.

FREQUENCY OF FERTILIZATION AND GROWTH OF CONTAINERIZED SEEDLINGS

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ABSTRACT

Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* (Moench) Voss) were grown in the greenhouse for 18 weeks and under three nutrient regimes: 1) weekly fertilization; 2) continuous fertilization, i.e., fertilizer applied whenever cavities were sufficiently dry (two to three times per week); and 3) continuous fertilization at half strength. Lodgepole pine showed no difference in height and root-collar diameter due to treatment. White spruce was taller under continuous fertilization, but root-collar diameter was similar with all treatments. Shoot:root ratio of white spruce also increased significantly with continuous fertilization. After 18 weeks, pH of the growing medium had decreased and salinity had increased significantly under continuous fertilization, and there was heavy moss growth and salt accumulation on the surface of the medium. Continuous fertilization resulted in greater uptake of N, K, Fe, and Mn, but only N in lodgepole pine was improved significantly compared to weekly application. Continuous fertilization is unnecessary; the practice results in morphologically inferior spruce and exposes both species to great physiological risk.

INTRODUCTION

In the production of containerized seedlings, different frequencies of fertilization have been used. A frequency of twice per week has been used in British Columbia (Brix and van den Driessche 1974), and application once per week was the practice in the Pacific Northwest (Owston 1974), the Canadian prairie provinces (Carlson 1983; Edwards and Huber 1981), and the Maritimes (Hallett 1981). Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings grown in shade frames in British Columbia (van Eerden 1974) showed a positive response to increased frequency of fertilizer application, and it was later reported (Matthews 1981) that growers were advised to inject soluble fertilizer into the irrigation system at almost every watering. In a greenhouse trial in Alberta[1], weekly fertilization produced superior lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* (Moench) Voss) seedlings

[1] Edwards, I.K. 1982. A CFS-Grace fertilizer trial using containerized conifer seedlings. Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. File Rep. NOR-10-35.

compared to continuous fertilization (application whenever the cavities required watering). Seedlings grown under continuous fertilization were characterized by succulent foliage, flaccid stems, and high shoot:root ratios. In 1986, satisfactory growth of black spruce (*Picea mariana* (Mill.) B.S.P.) with continuous fertilization was reported at Pineland Provincial Forest Nursery in Hadashville, Manitoba[2], and continuous fertilization was being recommended by sources within the fertilizer sales community. In 1987, a greenhouse experiment was set up to determine the effect of frequency of fertilization on growth of containerized lodgepole pine and white spruce.

MATERIALS AND METHODS

Lodgepole pine and white spruce were sown in peat-filled Spencer-Lemaire Five containers (cavity volume = 55 cm; 70 cavities per tray) in mid-February and allowed to grow for 18 weeks. Prior to filling the trays, the peat was adjusted to pH 5.2 using calcium carbonate. The greenhouse environment was as follows: temperature, 24°C day and 16°C night; relative humidity, 62-65%; light intensity (high pressure sodium lamps), PAR = 260 $mol \cdot m^{-2} \cdot s^{-1}$; and photoperiod, 18 hours.

Beginning 21 days after germination, three fertilization regimes were imposed as follows: 1) weekly application of the formulation recommended (Carlson 1983) for pine and spruce, 125 ppm nitrogen (N) + 60 ppm phos phorus (P) + 159 ppm potassium (K); 2) continuous application of the formulation recommended in 1); and 3) continuous application of the formulation at half strength, i.e., 63 ppm N + 30 ppm P + 80 ppm K. Fertilization consisted of complete saturation of each cavity, at which time excess nutrient solution drained away. The fertilizer solution recommended by Carlson (1983) also contained micronutrients at the following concentrations: iron (Fe), 5.5 mg/L; manganese (Mn), 0.34 mg/L; boron (B), 0.30 mg/L; zinc (Zn), 0.11 mg/L; copper (Cu), 0.02 mg/L, and molybdenum (Mo), 0.01 mg/L. Trays receiving weekly fertilization were watered one to two times between each application; those receiving continuous feeding were never watered but received the fertilizer solution whenever they were judged to be sufficiently dry.

Measurements of height and root-collar diameter (RCD) were made at seedling ages of 6, 12, and 18 weeks. In addition, at 18 weeks, mean shoot dry weight and root dry weight were recorded for 25 seedlings. Observations on the appearance of seedlings and growing medium were recorded, and after 18 weeks the pH (paste method) and electrical conductivity (saturated extract) were determined (McKeague 1978). Following harvest, the foliage was analyzed for N (Kjeldahl method), P, K, Ca, Mg, S, Fe, Mn, and Cu, using ICAP spectrometry after nitric acid digestion[3]. Significance of the difference between means was compared using Student's *t*-test (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Lodgepole pine at 6 weeks was taller with continuous feeding, but there was no significant difference in height between nutrient regimes at 18 weeks (Table 1). Root-collar diameter

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[2] Personal communication from R. Cameron, Superintendent, Pineland Provincial Forest Nursery, Hadashville, Manitoba, June 1987.

[3] Personal communication from Y.P. Kalra, chemist, For. Can., North. For. Cent., Edmonton, Alberta, September 1986.

was also similar for all treatments. Results for white spruce (Table 2) indicated significantly taller seedlings under continuous fertilization, but there was no significant difference in root-collar diameter. Shoot: root ratio of lodgepole pine was least under a continuous nutrient regime, but it was not significantly different from that receiving weekly fertilization (Table 3). In white spruce, shoot:root ratio was least under weekly fertilization and significantly greater with continuous feeding.

Whereas the morphology of lodgepole pine was not affected significantly by frequency of fertilization, there was an important implication for white spruce. Continuous application of nutrient solution at full strength resulted in spindly seedlings, i.e., taller but with no larger stems, and the seedlings were more unbalanced (top-heavy). Both characteristics (spindliness and high shoot:root ratio) render these seedlings less desirable for outplanting. Continuous fertilization at half strength did not improve seedling morphology relative to weekly application. Although there was no difference in the morphology of pine, less acceptable spruce in terms of spindliness and shoot:root ratio was produced.

Following 18 weeks of culture, the pH of the growing medium decreased under a full-strength continuous regime, and electrical conductivity increased significantly compared to the peat fertilized weekly (Table 4). In the half-strength continuous regime, pH and electrical conductivity of the medium were similar to those in the weekly regime. The ideal pH for growing prairie conifers is 5.0-6.0, and the implication for seedling growth in this case is obvious. The high level of salinity that accumulated under full-strength continuous fertilization is potentially deleterious. At an electrical conductivity of 4 mS/cm, all but the most salt-tolerant plant species will suffer toxic effects (Richards 1954). As the growing medium dries between applications, salts are concentrated in the material and conductivity readings may increase by a factor of four (Richards 1954). The practice of continuous feeding at full strength leaves little room for error in the event that an application is delayed unduly.

Physical observations made on the seedlings and growing medium indicated that under continuous feeding at full strength there was a heavy accumulation of salt and thick moss growth on the surface (Table 5). Continuous feeding at half strength resulted in no surface build-up of salt, but there was a moderate amount of moss growth. Weekly application of nutrients resulted in no salt accumulation, and only a trace of moss appeared following increased density of foliage. In all cases, the seedlings had a normal green color. White spruce had an average of 10, 12, and 15 side branches under the weekly, half-strength continuous, and full strength continuous regimes, respectively.

Nutrient concentration in the foliage of lodgepole pine (Table 6) indicated that seedlings grown under the weekly regime were lower in N, K, Fe, and Mn than those receiving continuous feed at full strength. All other nutrients were similar in foliar concentration regardless of nutrient regime; however, only N concentration was below the range of sufficiency for lodgepole pine (Table 7), based on suggested standards (Swan 1972). Iron and manganese are found in tree species in wide ranges of concentration, and although no sufficiency levels exist per se, the present levels are within the ranges of concentration that have been reported.

In the case of white spruce, foliar concentration of nitrogen, potassium, iron, and manganese in seedlings from the weekly regime were also lower than the levels that developed from continuous treatments (Table 8), but no

Table 1. Height and root-collar diameter (RCD) of lodgepole pine seedlings at 6, 12, and 18 weeks under different nutrient regimes

Nutrient regime	Height (cm)			RCD (mm)		
	6 wk	12 wk	18 wk	6 wk	12 wk	18 wk
Weekly	5.5 a[1]	7.2 a	8.4 a	1.2 a	2.4 a	3.1 a
Full-strength continuous	6.4 b	7.5 a	8.3 a	1.3 a	2.4 a	3.3 a
Half-strength continuous	5.3 a	7.3 a	8.6 a	1.2 a	2.4 a	3.3 a

[1] Within columns, means followed by the same letter are not significantly different (5%) according to Student's *t*-test; n = 25.

Table 2. Height and root-collar diameter (RCD) of white spruce seedlings at 6, 12, and 18 weeks under different nutrient regimes

Nutrient regime	Height (cm)			RCD (mm)		
	6 wk	12 wk	18 wk	6 wk	12 wk	18 wk
Weekly	5.3 a[1]	11.9 a	17.8 a	0.8 a	2.0 a	3.1 a
Full-strength continuous	5.8 b	11.5 a	19.2 b	0.9 a	1.9 a	3.0 a
Half-strength continuous	5.1 a	11.8 a	18.6 b	0.8 a	2.2 a	3.0 a

[1] Within columns, means followed by the same letter are not significantly different (5%) according to Student's *t*-test; n = 25.

Table 3. Shoot:root ratio of lodgepole pine and white spruce at 18 weeks under different nutrient regimes

Nutrient regime	Lodgepole pine shoot:root ratio	White spruce shoot:root ratio
Weekly	3.7 ab[1]	4.2 a
Full-strength continuous	3.3 a	6.1 b
Half-strength continuous	4.2 b	5.9 b

[1] Means followed by the same letter are not significantly different (5%) according to Student's *t*-test; n = 25.

Table 4. The pH and electrical conductivity (EC) of growing medium (peat) in trays after 18 weeks

Nutrient regime	pH	EC (mS/cm)
Weekly	5.45	0.75
Full-strength continuous	4.58	2.20
Half-strength continuous	5.66	0.72

Table 5. Observations of spruce seedlings and growing medium from trays in different nutrient regimes

Nutrient regime	Observations
Weekly	No evidence of salt build-up; trace of surface moss only; appearance normal; an average of 10 side branches per spruce seedling.
Full-strength continuous	All cavities had heavy salt build-up (white appearance); also thick moss layer on surface of peat; deep green foliage; 15 side branches per spruce seedling.
Half-strength continuous	No salt accumulation; some moss growth; appearance normal; 12 side branches per spruce seedling.

Table 6. Nutrient concentration in foliage of lodgepole pine seedlings at 18 weeks under different nutrient regimes

Nutrient element	Nutrient regime		
	Weekly	Full-strength continuous	Half-strength continuous
N (%)	1.46	1.96	1.65
P (%)	0.21	0.22	0.22
K (%)	0.81	1.04	0.84
Ca (%)	0.33	0.41	0.33
Mg (%)	0.17	0.12	0.16
S (%)	0.16	0.17	0.17
Fe (mg/kg)	60	109	105
Mn (mg/kg)	53	142	66
Cu (mg/kg)	4	4	4

Table 7. Suggested standards[1] for evaluation of foliage analysis (%)

Nutrient element	Species	Range of deficiency	Range of sufficiency
N	Lodgepole pine	<1.20	1.70-3.00
	White spruce	<1.30	1.50-2.50
P	Lodgepole pine	<0.10	0.17-0.40
	White spruce	<0.14	0.18-0.32
K	Lodgepole pine	<0.30	0.50-1.10
	White spruce	<0.30	0.45-0.80
Ca	Lodgepole pine	<0.06	0.08-0.30
	White spruce	<0.10	0.15-0.40
Mg	Lodgepole pine	<0.07	0.09-0.16
	White spruce	<0.06	0.10-0.20

[1] Swan 1971, 1972.

Table 8. Nutrient concentration in foliage of white spruce seedlings at 18 weeks under different nutrient regimes

Nutrient element	Nutrient regime		
	Weekly	Full-strength continuous	Half-strength continuous
N (%)	1.69	2.23	1.88
P (%)	0.30	0.32	0.29
K (%)	0.97	1.27	0.97
Ca (%)	0.65	0.70	0.54
Mg (%)	0.18	0.15	0.14
S (%)	0.14	0.16	0.14
Fe (mg/kg)	73	164	74
Mn (mg/kg)	83	240	66
Cu (mg/kg)	3	3	3

element was below the range of sufficiency (Swan 1971). All other elements were similar in foliar concentration regardless of the nutrient regime in which the seedlings were reared. This demonstrated that in the context of seedling nutrition it is pointless to apply nutrient solution continuously in the culture of prairie provenances of lodgepole pine and white spruce. Although lodgepole pine could benefit from the weekly application of a nutrient solution containing a higher concentration of nitrogen, unfavorable morphological and physiological effects should be avoided.

CONCLUSIONS

Continuous application of fertilizer solution in the greenhouse culture of lodgepole pine and white spruce is counterproductive. The practice results in morphologically inferior white spruce seedlings, although the morphology of lodgepole pine is not affected. Under continuous fertilization, both species are physiologically put at risk because of the build-up of salts on the surface of the growing medium and, consequently, unacceptably high levels of salinity in the cavities, as expressed by electrical conductivity. When seedling nutrition is considered, there is no benefit to white spruce from continuous fertilization, and in lodgepole pine only the uptake of nitrogen is enhanced significantly.

Compared to weekly fertilization, the increased costs associated with fertilizer purchase and human resources (applicator, time) for continuous fertilization are not warranted. Even if financial considerations are ignored, crop quality is jeopardized, and this is unacceptable. Although the study did not involve induction of dormancy, electrical conductivity results indicated that leaching of salts from the cavities would occur less easily in trays subjected to continuous fertilization, and such seedlings would be at a disadvantage in the development of cold hardiness.

ACKNOWLEDGMENTS

The greenhouse study, including data collection and summary, was conducted by Joe van Dyk. On occasion, he was assisted in watering or fertilizing by Frank Dendwick and summer student Roman Wasarab.

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TOPDRESSING TRIALS AT PINELAND FOREST NURSERY

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INTRODUCTION

The Pineland Provincial Forest Nursery is situated 100 km east of Winnipeg, on the west bank of the Whitemouth River. The soil types found on-site vary from silt to sand to clay. In construction of the bare-root fields, sedge peat (pH 7) and sand were added. The pH of the native soil is high, and actual limestone is evident in some fields. In 1976 the nursery started using sulfur to lower the pH and in 1986 began using screened sphagnum peat (pH 4) to bring up the organic content of the fields.

Problems that are evident in the fields are phosphorus and potassium deficiencies, and uneven growth of seeded fields due to extreme pH values. To help us develop an effective topdressing program, a 3-year contract was signed with Dr. Vic Timmer, Associate Professor of Forest Soils at the University of Toronto. Under his guidance, the nursery will run a series of trials that deal with our specific problems. He will also do all of the soil and foliage analysis for the nursery over the next 3 years.

MATERIALS AND METHODS

Three trials were established in 1987 covering different aspects of the topdressing program: phosphorus additions, pH adjustment, and nitrogen additions.

Trial 1--Phosphorus

Different soils vary in their phosphorus fixation capacities. Until now, phosphorus (P) in the form of ordinary superphosphate (0-20-0) or triple superphosphate (0-45-0) has been added to bring P to an optimum level of 30 mg/(100 g). Even after following recommended application rates of 20 kg/ha of elemental P for every mg/(100 g) that the actual soil levels are lower than optimum, some seedlings were showing signs of acute phosphorus deficiency. The objectives for Trial 1 are to determine 1) the relationship between phosphorus added to the soil and phosphorus available to seedlings and 2) the relationship between available phosphorus in the soil and seedling growth.

During land preparation, plots were established and shielded from field applications of phosphorus. After beds were shaped, applications of four different rates of phosphorus were done by hand and rototilled in. Black spruce seedlings were transplanted into the plots 6 days later. Soil and foliage samples were collected at the start of the trial, and a second set will be collected once trees are dormant. Growth parameters of the seedlings will also be measured once the seedlings are dormant.

Trial 2--pH

The pH values of our fields vary from 4.6 to 7.6. This range probably reflects differing buffering capacities, as all fields have received sulfur applications over the last 10 years to reduce pH. The objective of Trial 2 is to determine the relationship between sulfur and peat moss additions and changes in soil pH.

The field that was chosen for this trial was considered average, with a

pH of 6.5. During land preparation for transplanting, an area was set aside that did not receive field applications of peat or sulfur. Once the beds were shaped, plots were marked out, and peat and sulfur applications were done by hand and rototilled in. Different treatments included peat at three different rates with no sulfur, sulfur at three different rates with no peat, and sulfur at three different rates with peat moss at the field rate (350 m^3/ha). Prior to treatments, soil pHs were determined and mapped out so that any preexisting variations could be noted. Soil samples will be collected in the fall to determine the results.

Trial 3--Nitrogen

The present topdressing regime for rising 1-0 stock prescribes ammonium sulphate applications at 150 kg/ha every 10-14 days, starting when secondary roots are present and ending August 1st. The objective of Trial 3 is to compare the effects of two different types of nitrogen (N) fertilizers, ammonium phosphate (MAP), and an extended regime versus the present regime, on seedling growth.

Plots were established in rising 1-0 stock, with one replication in red pine, and one replication in jack pine. The field had received two applications of ammonium sulfate at 150 kg/ha prior to trial start-up. During the period of the trial, the control and MAP plots were shielded from field nitrogen applications, and applications of MAP were made by hand. The MAP was applied at the same rate of elemental N as the ammonium sulfate. To test the extended regime, all applications were made by hand. Growth parameters of the seedlings will be measured once seedlings are dormant.

RESULTS AND DISCUSSION

Results from these trials will not be available until later in the fall; however, preliminary work by Dr. Timmer in setting up these trials has already yielded some relevant data that indicate that certain practices in use at the nursery are not appropriate to the type of soil conditions present. For example, variations of 3 pH points exist within fields, and as a result, bulk soil sampling is not accurate enough to be able to prescribe the correct topdressing. A detailed pH mapping of each field is being undertaken now.

CONCLUSION

These three trials and others carried out over the next 2 years should provide us with the data required to set up a sound topdressing program, which will enable us to produce better-quality seedlings.

EFFECTIVE USE OF WEATHER RECORDS IN CONJUNCTION WITH VIABILITY TESTS FOR MONITORING STOCK QUALITY

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INTRODUCTION

Weather records are often used in the daily operations of tree nurseries. If long-term records are available for a particular nursery or can be obtained from the nearest available weather station, very comprehensive pictures of the expected mean daily weather conditions can be drawn up as an aid in planning nursery operations.

Parameters such as daily mean, minimum, and maximum air, ground level, and soil temperatures; growing-degree days; hardening-degree days; wind velocity, direction, and duration; precipitation; period from first to last frost; hours of sunshine; day length; and amount of snow cover are monitored at many weather stations across the country and are available to clients. These data can be summarized and depicted graphically. Local daily parameters can be recorded and plotted over the long-term averages. This information should then be used by nursery managers for planning daily, monthly, and annual operations. Unfortunately, this is not always done.

At the 1986 Prairie Federal-Provincial Nurserymen's Meeting in The Pas, Manitoba, we gave some results of tests being conducted on monitoring the viability of overwintering container stock (Dymock and Dendwick 1987). At that time, the use of daily weather records was also discussed in conjunction with the use of these tests. It was also pointed out that the weather records had the potential for use in a postmortem in the eventuality of a failure in the overwintering crop.

The effective use of these records is the theme of this discussion. The types of records available and how they can influence the decision-making process for nursery operations will be reviewed. Examples to be presented will relate to the research experiences from the Northern Forestry Centre (NoFC). These have the same potential for determining the success or failure of a crop in a production nursery regardless of whether it is a container or bare-root operation or both.

MATERIALS AND METHODS

Growing Schedules

Containerized seedlings of various conifer species have been reared in the greenhouses at NoFC each spring since May 1982 and for each successive year up to and including 1987 as part of the study on overwintering physiology of conifer seedlings. All seedlings have been reared using Schedule 2 for Frost Hardiness Zone 3 (Carlson 1983).

During 1982 and 1983, seedlings were grown under fluorescent lights that provided a minimum photosynthetic photon flux density (PPFD) of 57.6 micromoles per square metre per second of ($\mu mol \cdot m^{-2} \cdot s^{-1}$) photosynthetically active radiation (PAR) for up to 8 weeks during the early (greenhouse) rapid-growth period. The seedlings were then moved outdoors (to complete their later rapid growth) on June 24,

1982, and July 4, 1983. The rapid growth phase ended August 24 and August 31 of each year, respectively. On these dates, the hardening phase of Carlson (1983) was initiated and continued through to mid-October of each year as weather conditions permitted.

From 1984 onwards, seedlings were grown in the greenhouses under high pressure sodium vapor lamps (minimum PPFD = 250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PAR for 14 weeks. They were then moved outdoors for hardening-off (Carlson 1983) under decreasing, ambient daylength and temperatures during mid to late August of each year as shown in Figure 1. The start of the vertical black lines, which indicate the daily range in temperatures, coincides with the date of moving seedlings outdoors to the shadeframes or cold frames. It has been recommended by Carlson (1983) that seedlings reared in Hardiness Zone 3 should not be moved outdoors to begin natural hardening any later than August 20. For our work it was usually possible to adhere to this schedule.

Test Sampling Schedules

Sampling was initiated in mid to late August and continued on a weekly or biweekly basis depending on the year, the species under study, and whether it was an initial or replicate sampling year. The dormancy tests used were the oscilloscope/square wave deformation method of Ferguson, Ryker, and Ballard (1975) for monitoring stem (cambial) activity and the root growth capacity test of Burdett (1979) for determining root activity. Rating and scoring were according to the methods outlined by Dymock and Dendwick (1987).

Cold hardiness-freezing tolerance tests were carried out on seedlings as described by Dymock and Dendwick (1987). A modified version of the conductivity test of Colombo, Webb, and Glerum (1984) was employed for rapid testing of both shoot and root cold-hardiness. Shoot and root damage and seedling survival were assessed after 4 weeks, according to the rating and scoring system outlined by Dymock and Dendwick (1987).

Environmental Parameter Monitoring

Historical weather records were obtained from the NoFC library in Edmonton, Alberta, for 1941-70. Microfiche copies of weather records for each year beginning with January 1983 were purchased from the Climate Control Centre, Atmospheric Environment Service (AES), Environment Canada, Downsview, Ontario. An excellent summary of Canadian climatic conditions and parameters by Hare and Thomas (1974) is very useful as a primary reference source.

Hourly temperature recordings in the NoFC shadeframes and cold frames were initiated during September 1983 using a 24-channel electro-mechanical Honeywell Recorder that was equipped with 24 copper-constantan thermocouples. Thermocouples were placed in the centres of container root plugs, at seedling bud level, in the air 1.8 m above the seedlings, and at ground level. Since January 1986 the temperature recordings have been made using a microprocessor-controlled Campbell Scientific CR-7 datalogger equipped with copper-constantan thermocouples placed as above.

All seedling trays were on wire racks in the shadeframes and cold frames. These were approximately 3 cm above the gravel bed of the shadeframes and cold frames. The shadeframes and cold frames were initially covered with shade cloth, which allowed for transmission of 50% of the available light. The shade cloth has since been replaced with Paraweb vinyl shading (55%) that allows snow to fall onto the seedlings.

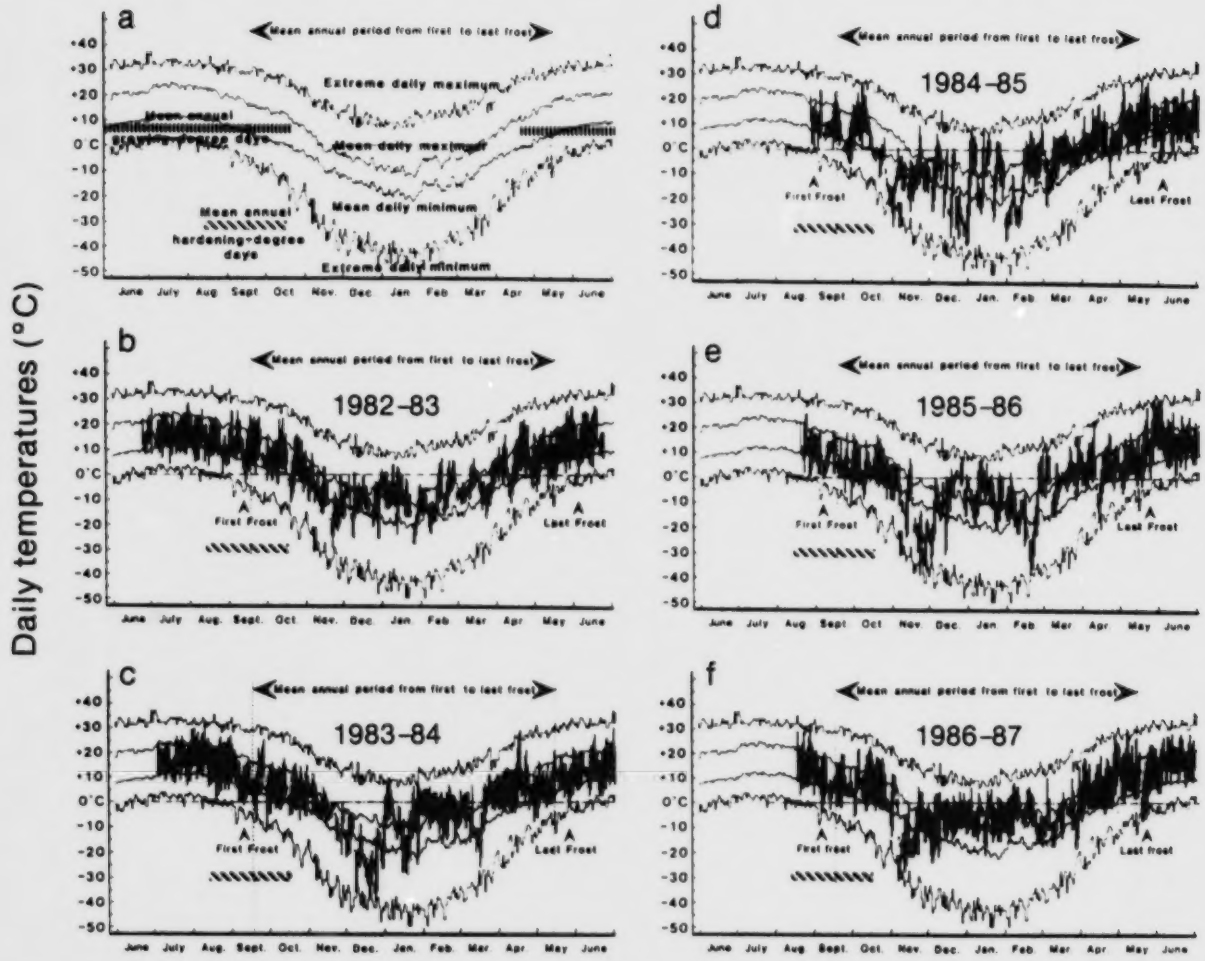

Figure 1. **Mean annual temperature data and temperature records for each experimental overwintering season.**

Details of the features of Figures 1a-f are outlined in the Materials and Methods and Results and Discussion sections.

RESULTS AND DISCUSSION

Weather Records and Recording Stations

First of all, what types of records are available? The Atmospheric Environment Service's Climate Control Centre provides very complete weather records for all weather stations that report to them. Up to the end of 1982, these were available free of charge and could be found in most libraries. Since January of 1983, the annual daily summaries from the Climate Control Centre system have become available on microfiche. These must be purchased in their entirety, but they are available at the NoFC library. More recently, detailed records have become available on computer tape. These can be purchased for individual weather stations for as long as these stations have been recording. These records will include all parameters that have been monitored at each weather station.

The Northern Forestry Centre is located at approximately 53°29'N latitude and 113°32'W longitude; altitude 700.1 m. The data shown in Figure 1a are the mean daily minimum and maximum temperatures for the 1941-70 period, at Edmonton Municipal Airport (53°34'N latitude, 113°31'W longitude; altitude 671 m) and the daily extremes for the Edmonton area recorded between 1885 and 1985. The Edmonton Municipal Airport weather station is closest to NoFC and has the longest recording history. We have also used weather records from the Ellerslie station (53°25'N latitude, 113°33'W longitude; altitude 694 m). This station was located on the University of Alberta Experimental Farm on Ellerslie Road, south of NoFC. Both stations are about the same distance from NoFC.

The Ellerslie station was located in a wide open area similar to the locale around NoFC, which is situated on the southern edge of the central University of Alberta farm on the south side of Edmonton. Environmental conditions at the two sites are very similar year-round. Where data are missing in NoFC site records, data from the Ellerslie station have been used.

Data collection at the Ellerslie station was discontinued December 31, 1986, but a new weather station at the University of Alberta Metabolic Centre (53°31'N latitude, 113°32'W longitude; altitude 668 m) began operations on January 1, 1987. This station is less than 1 km to the northeast of NoFC at the north edge of the University of Alberta Central Farm. The geographic and climatic conditions at this site are virtually identical to those at NoFC. Data from this station are now used to replace missing data from NoFC records.

Analysis of Weather Records

In Figure 1a the mean daily minimum and maximum temperatures for the period 1941 to 1970 and the extreme daily minimum and maximum temperatures for the 1885 to 1985 period have been plotted from June to June. This corresponds to the period during which all of the overwintering physiological studies have been carried out since 1982. Superimposed at the top of Figure 1a, between the black arrows and indicated by the heavy vertical dashed lines, is the mean annual period from first to last frost for 1941 to 1970. This period is 238 days long, from the 19th of September through to the 14th of May. This also indicates that the mean (normal) growing season is 127 days long for the Edmonton area proper.

Using this data, one can calculate the mean annual growing-degree days (see Figure 1a--heavy dashed horizontal line), which can be defined as the number of degrees per day that the daily mean temperature is above 5.5°C (Hare and Thomas 1974). Daily growing-degree days can be added to obtain the

cumulative growing-degree days over the season. For the Edmonton area proper, the mean annual growing season extends from April 19 to October 18 (Fig. 1a), resulting in a mean value of 1330.3 growing-degree days over the season.

Using data in Figure 1a one can determine the expected periods of frost and time the movement of seedlings from the greenhouse to the outdoors. This minimizes the chance of frost damage both in the spring, for a spring-planted crop, or in late summer for a crop that is to be fall-planted or subsequently overwintered. As previously mentioned, the recommended last date for safely moving seedlings outdoors for the Edmonton area (Hardiness Zone 3) is the 20th of August (Carlson 1983).

One can also determine the cumulative hardening-degree days that may be available to ensure that a crop moved outdoors has sufficient exposure time to both declining natural daylength and dropping night temperatures. This is a strict requirement that must be met in order for the seedlings to harden-off adequately to ensure survival during overwintering. Hardening-degree days can be defined as the cumulative daily minimum difference between 10°C and the temperature at root level above 0°C (D'Aoust and Cameron 1982). For bare-root stock, this is measured at a depth of 15 cm. For container stock it is the root plug temperature. At NoFC the mean period that is used for calculating the cumulative hardening-degree days for container stock is from August 14 to October 15 (shown in Figures 1a-f as diagonally slashed horizontal lines). This yields a total of 295.8 cumulative hardening-degree days for container stock that is moved outdoors by August 14.

For each experimental season, comparing the daily temperature range with the long-term average allows for analysis of each season compared to the expected normals. By overlaying the recorded temperature ranges in black (Figs. 1b-f), it is apparent whether above average, normal, or below average temperatures prevailed at any given time or over the entire winter. It is then possible to diagnose the reasons for success or failure of a particular overwintered container crop that was stored outdoors under ambient conditions.

Occurrence of Frost and Freezing Periods

During any outdoor growing season or the hardening-off period, the incidence and severity of frost is expected to have varying effects on the crop, depending on the degree to which it has hardened. Frost is considered to occur when the minimum temperatures reach 0°C (Hare and Thomas 1974). A light frost can be defined as exposure to temperatures from 0 to -2.5°C; a hard frost can be defined as exposure to temperatures from -2.6 to -5.0°C; temperatures falling below -5.0°C can be defined as a severe frost in accordance with those definitions of Hare and Thomas (1974) and DeLucia and Smith (1987).

The duration of exposure to particular frost conditions will have a significant influence on seedling damage and viability. This is also true for the time of frost occurrence during the hardening period. Early and severe frost conditions are expected to be far more detrimental to a crop during hardening-off than would later, milder frosts (Kramer and Kozlowski 1979; Levitt 1980).

1982-83 Seasonal Weather Trends

The 1982-83 season (Fig. 1b) was the closest to the long-term averages of any of the experimental seasons. It did exhibit a short below-normal period in late November 1982 and several brief periods of moderately

below normal daily temperatures later during the winter.

The seedlings, which were originally moved outdoors on June 24, experienced a total of 336.5 hardening-degree days between June 24 and October 24. This was 40.7 hardening-degree days (13.8%) above the expected cumulative mean of 295.8.

The first frost (light) occurred on September 12, 1983, which was 7 days earlier than normal. From September 12 to October 24 there were eight light, five hard, and three severe fall frosts. The last frost in the spring of 1983 occurred on June 3, 1983, 20 days later than normal (mean last spring frost date is May 14).

1983-84 Seasonal Weather Trends

Seedlings were moved outdoors on July 4 and were allowed to complete the rapid growth phase in the shade-frames. The 1983-84 season (Fig. 1c) was the second of five seasons in a row that experienced unusually cold (below normal) periods in late November and December. These were followed by unusually warm periods throughout mid-January, most of February, and into early March of 1984. A second brief below-normal period occurred in the middle of March, followed by a warm April.

These seedlings experienced a total of 270.5 hardening-degree days between July 10 and November 2, 1983, 25.3 hardening-degree days (8.6%) less than normal. The first fall frost (light) occurred on September 6, 1983, 13 days earlier than normal. This was followed intermittently by 16 light, 11 hard, and 3 severe fall frosts up to November 2. The last spring frost of 1984 fell on May 25, 1984, 11 days later than normal.

1984-85 Seasonal Weather Trends

The 1984-85 season (Fig. 1d) began on August 27, the date that seedlings were moved outdoors. It was climatically very severe, as has been previously reported by Dymock and Dendwick (1987). It began with a light, early frost on August 30, just 3 days after the seedlings were moved outdoors. This frost was 20 days earlier than normal and was followed by a below-normal period of light-to-severe frost and freezing conditions and snow during the third week of September. After this there was a severely cold (well below normal) period during late October, most of November, and into December.

The lateness in moving seedlings out of doors coupled with the incidence of frost resulted in the seedlings receiving only 172.5 hardening-degree days from August 27 to October 14. This was 123.3 hardening-degree days (41.7%) below the mean. During this time, seedlings were exposed to eight light, two hard, and two severe frosts, most of which occurred from September 22 to 29.

Above-normal conditions prevailed throughout most of January 1985, followed by an additional below-normal period in late January and early February. The remainder of the 1984-85 winter was very close to or slightly above normal. There were two more brief but severe freezing periods in late April and late May that came close to setting new records for extreme low temperatures on their respective dates. The last spring frost occurred on June 3, 1985, 20 days later than normal.

1985-86 Seasonal Weather Trends

The 1985-86 season (Fig. 1e) began on August 19 and was characterized by

below-normal minimum temperatures in late August 1985, throughout most of September, and during the first week of October. The first fall frost (light) occurred on September 6, 1985, 13 days earlier than normal. Well below normal freezing temperatures prevailed throughout most of November and for a brief period in mid-December. Above-normal conditions then prevailed throughout the rest of December.

Seedlings had been moved outdoors on August 19, 1985. Between this date and October 21 they were exposed to 191.5 hardening-degree days, 104.3 fewer hardening-degree days (35.3%) than normal. Also during this time they were exposed to 17 light, 5 hard, and 4 severe frosts.

Daily temperatures in January 1986 were well above normal throughout much of the month. This was followed by more normal conditions in the first half of February, when a brief below-normal period of extreme cold occurred followed by a period of unusually warm conditions into early March of 1986. A brief period of near-record freezing conditions occurred during mid-April, followed by near normal conditions. The final spring frost occurred on May 23, 1986, 9 days later than normal.

1986-87 Seasonal Weather Trends

The 1986-87 season (Fig. 1f) began under favorable, very near normal conditions. Seedlings were moved out of doors on August 18, 1986. The first fall frost (light) occurred 13 days earlier than normal, however, on September 6. Although several brief periods of below-freezing minimum temperatures occurred throughout September and October, conditions were close to or slightly above normal for those 2 months. Much of November was characterized by very low temperatures, but these were not record lows. December highs were normal in the early part of the month. The lows were below normal during the second week, but the conditions moderated and were generally above normal throughout the rest of December 1986.

During the hardening-off period, the seedlings were exposed to 281.3 cumulative hardening-degree days between August 18 and November 4. This was only 14.5 hardening-degree days (4.9%) less than normal. They were also subjected to 14 light, 9 hard, and 4 severe frosts during this period.

Above-normal (or very near normal) conditions prevailed throughout much of January, February, March, and April of 1987. One brief below-normal period occurred in late March. From May 19 to 23, very severe below-normal conditions brought heavy snowfall followed by near-record low temperatures and high winds. During these 5 days, there were 3 days of hard frost and one severe frost. These conditions inflicted severe freezing damage to many trees and shrubs in the region, which were flushing early due to the warm spring conditions that had prevailed throughout April and most of May.

Seasonal Trends in Black Spruce Viability

Figures 2 and 3 illustrate the seasonal trends in black spruce stem (cambial) activity, as measured by the oscilloscope/square wave deformation method of Ferguson, Ryker, and Ballard (1975), root activity as measured by the root growth capacity test of Burdett (1979), and whole seedling cold hardiness (freezing tolerance) as determined by Dymock and Dendwick (1987). The scoring systems used in evaluating results were those reported by Dymock and Dendwick (1987) for each of the tests employed.

Figure 2 can be compared with weather trends in Figure 1c for the 1983-84 season, and Figure 3 can be

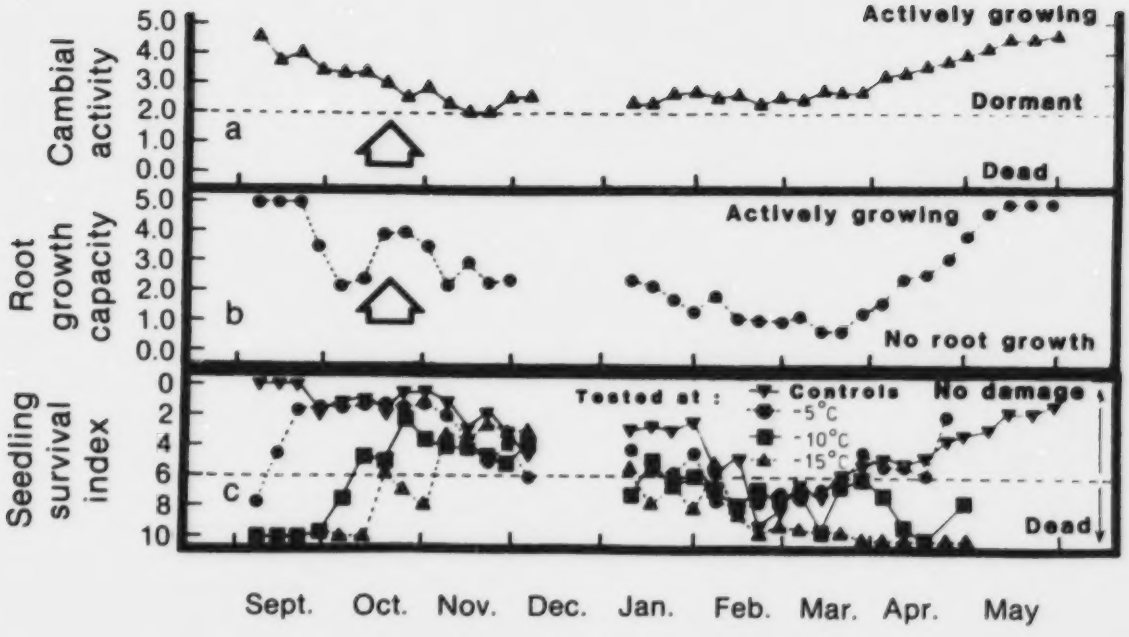

Figure 2. **Dormancy, freezing tolerance, and survival data for black spruce seedlings during the 1983-84 overwintering period.**

Cambial activity, root growth capacity, and seedling freezing tolerance-survival were determined according to the methods described by Dymock and Dendwick (1987). Each data point represents the mean value for either 10 (cambial activity, freezing tolerance and survival) or 20 (root growth capacity) seedlings.

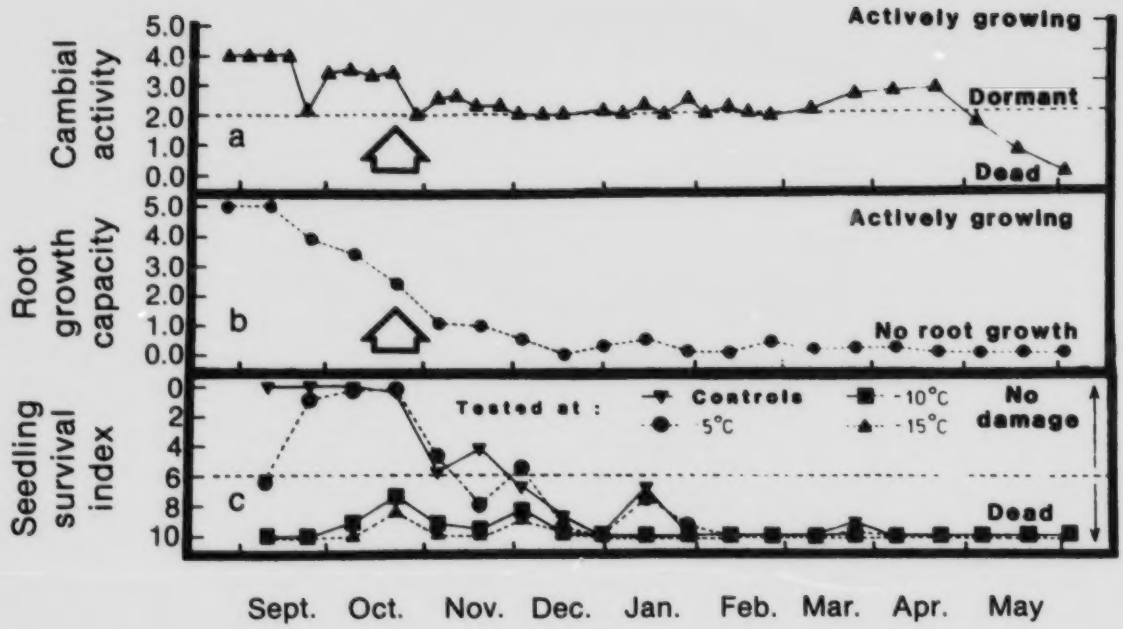

Figure 3. **Dormancy freezing tolerance, and survival data for black spruce seedlings during the 1984-85 overwintering period.**

Cambial activity, root growth capacity, and seedling freezing tolerance-survival were determined according to the methods described by Dymock and Dendwick (1987). Each data point represents the mean value for either 10 (cambial activity, freezing tolerance and survival) or 20 (root growth capacity) seedlings.

compared with weather trends in Figure 1d for the 1984-85 season.

Black spruce seedlings have been shown to develop cold hardiness much more slowly than other species such as white spruce and red pine when hardened-off under similar conditions (Dymock and Dendwick 1987; Edwards 1987). During the 1983-84 season, cambial activity (Fig. 2a) declined gradually as the number of hardening-degree days accumulated, even in the presence of light-to-hard frosts in the latter part of September and into October 1983. Root activity (Fig. 2b) tended to more closely follow root temperature trends and showed a major peak of root growth capacity in late October to early November that occurred during a period of normal day and night temperatures and frequent light-to-hard frosts. The total number of hardening-degree days came to within 8.6% of the normally expected values, suggesting that these seedlings had sufficient time to harden-off.

Further evidence for this can be seen in Figure 2c, where seedlings can be seen to have developed hardiness to each of the freezing test temperatures with time, reaching moderate hardiness to -15°C by late November.

During the 1984-85 season, however, a much different picture emerges for those black spruce seedlings (Figs. 1d and 3). Two early (light) frosts, within 6 days of moving the seedlings outdoors, caused visible shoot damage (data not shown). Eight consecutive days of light-to-severe frost from September 22 to 29 (Fig. 1d) were reflected in a sharp drop in stem cambial activity (Fig. 3a). Stem activity resumed as temperatures rose to normal in early October, but a second drop in stem activity parallels the sudden drop in temperatures and the increasing severity of freezing temperatures that occurred after October 15.

Root activity showed a steady decline during this time (Fig. 3b). Seedling freezing tolerance developed quickly to -5°C but achieved little beyond that, likely due to the numbers and severity of the frost events (Figs. 1d and 3c).

By October 14, total cumulative hardening-degree days reached only 172.5, which was 41.7% below normal. This can be partially accounted for by the lateness of moving the seedlings out of doors (August 27) and partially by the early frosts within 6 days. The second more-severe period during late September likely had a more-pronounced effect on arresting cold hardiness development after it had reached only -5°C.

Evidence reported by DeLucia and Smith (1987) for Engelmann spruce indicated that nightly air and soil temperatures down to -2.5°C would result in decreased rates of photosynthesis during the following day. If air and soil temperatures dropped to -5°C, substantial and irreversible reductions in photosynthesis would occur. As the black spruce seedlings that were used in this study were in containers outdoors, it is very likely that the shoots and roots were far more susceptible to extremes in temperature than would have been the case with bare-root stock.

Kramer and Kozlowski (1979), Levitt (1980), Tinus (1981), Carlson (1983), and Dymock and Dendwick (1987) have all reported on the increased sensitivity of roots to low temperatures. With this in mind and the data presented for the black spruce seedlings in the 1984-85 season, it is apparent that the roots (and to a lesser extent the shoots) suffered a series of severe, freezing events from which they were unable to recover in time to develop any further freezing tolerance beyond -5°C. The onset of temperatures that dropped below -15°C in the latter part of October was likely all

that was needed to kill or fatally injure most of the black spruce seedlings at that point.

Comparison of Black and White Spruce Viability During 1984-85

Data shown in Figures 1d and 4 illustrate the differences in development and maintenance of cold hardiness and dormancy in black and white spruce trees during the 1984-85 overwintering season. White spruce stem cambial activity shuts down more quickly in response to the early frosts than does black spruce (Fig. 4a). This can also be observed with root activity (Fig. 4b). Both species were moved out of doors later than should normally have occurred, and both species were exposed to the same numbers of hardening-degree days and incidents of frost.

In spite of this, white spruce seedlings were able to develop moderate cold hardiness to -15°C for both their shoots and roots by late November, as shown in Figures 4c and d. The roots were slower to develop hardiness to the same degree as the shoots. They also lost their hardiness to -15°C much earlier in the spring than did the shoots. The conductivity test results that are expressed as an index of injury (Fig. 4d) suggest that the black spruce seedlings (shoots and roots) were still viable as late as April, but this was not supported by survival test results (Fig. 4c). White spruce results were comparable for both tests.

These results provide strong support for the concept that white spruce is a more cold-tolerant species and in order to ensure its survival is extent than black spruce. This appears to be particularly true for the overwintering container situation and is supported by more-recent results from our ongoing research[1].

SUMMARY AND CONCLUSIONS

It is readily apparent from the data presented here that there should and could be a far greater emphasis put on monitoring daily, weekly, monthly, and annual changes in environmental parameters in and around production nurseries. Any such program should include a comprehensive analysis of historical weather records from the nursery or the closest available weather stations. Once a comprehensive weather picture has been constructed for the nursery, the daily records will provide a clearer picture of the status of any particular crop in production.

An assessment of a crop success or failure can be carried out as we have done with our research program on monitoring overwintering viability of our containerized seedlings. Results of tests conducted can be compared to weather factors that may have influenced survival of the seedlings.

Simply monitoring daily air and soil temperatures will allow nursery staff to calculate parameters such as growing-degree days and hardening-degree days. This information alone will give a good indication of both seedling growth and seedling hardening potential based on solar heat input. Monitoring of other parameters such as soil moisture, seedling water status, and wind velocity, direction, and duration could provide sufficient basic information for regulating irrigation practices.

The judicious monitoring of environmental parameters in production tree nurseries or in tree improvement

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[1] I.J. Dymock, unpublished data.

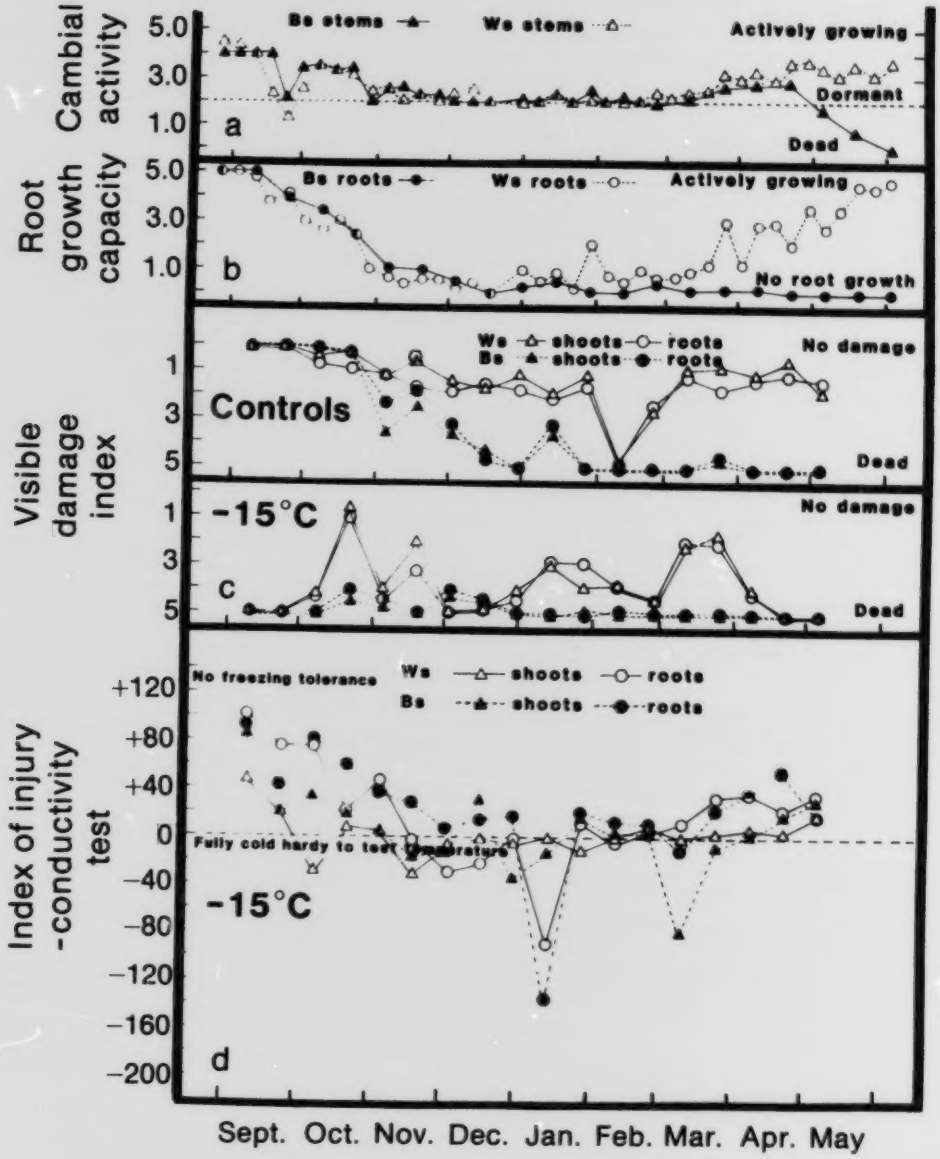

Figure 4. **Comparison dormancy, freezing tolerance, and visible damage data for black spruce (Bs) and white spruce (Ws) seedling shoots and roots during the 1984-85 overwintering period.**

Cambial activity, root growth capacity freezing tolerance tests to -15°C, conductivity tests on seedling shoots and roots, and visible damage assessments were carried out according to the methods described by Dymock and Dendwick (1987). Each data point represents the mean value for either 10 (cambial activity, visible damage index, index of injury-conductivity) or 20 (root growth capacity) seedling shoots or roots.

seed orchards will undoubtedly provide key information to assist nursery personnel in the effective management of their resources and in monitoring the progress of their stock.

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USE OF SUPPLEMENTAL LIGHTS IN CONIFER PRODUCTION: BENEFITS VS. COSTS

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INTRODUCTION

Tree seedlings grown in greenhouses for reforestation purposes or for use in tree improvement programs are known to have improved growth from the use of supplemental lights. Various types of supplemental lighting systems extend normal day lengths. This is of particular importance during our winters, when the critical day length is much less than the optimal photoperiod for good seedling growth. Day-length extension can play a significant role in achieving close to optimum growth rates if the intensity of the supplemental lights is sufficiently high for seedlings to reach near-optimal rates of photosynthesis.

To reach near-optimum growth rates, seedlings in the greenhouse must be exposed to sufficiently high levels of photosynthetically active radiation (PAR). This is defined as those wavelengths of light energy between 400 and 700 nm and covers the blue to red segments of visible light energy, with the red and blue light playing the greatest role in photosynthesis (Kramer and Kozlowski 1979; Vince-Prue and Canham 1983).

A light meter equipped with a quantum sensor is specifically designed for the accurate measurement of PAR. Output is expressed as the photon flux density of PAR, also referred to as the photosynthetic photon flux density (PPFD), which can be defined as the number of photons in the 400-700 nm waveband incident per unit time on a unit surface. Using the International System of Units (SI), PPFD is expressed in micromoles per square metre per second ($\mu mol \cdot m^{-2} \cdot s^{-1}$). Any supplemental lighting source that is used in a greenhouse environment can thus be evaluated for its output of PAR using a light meter equipped with a quantum sensor. For maximum photosynthesis to occur the available light should be relatively high in PAR, particularly in the red and blue spectra (Kramer and Kozlowski 1979). It is generally considered that it is the spectral balance of the light source rather than its overall light output that is likely to be important for morphogenetic effects (Vince-Prue and Canham 1983; Smith 1982), but the intensity and the duration of supplemental light are two components that cannot be overlooked and will be addressed in this paper.

At the 1984 Prairie Federal-Provincial Nurserymen's meeting, a report was presented by Dr. Ian Dymock (Dymock and Wilson 1986) on the effectiveness of using fluorescent versus high pressure sodium vapor lights as supplemental light sources in greenhouses for rearing conifer seedlings. The use of extended photoperiods with these two light sources was also examined. At the time of that report, the use of the combination of fluorescent plus incandescent lights had been reported on by Wheeler (1979). He reported significant increases in growth of greenhouse-grown lodgepole pine seedlings over nursery-grown controls using continuous lighting (24-h photoperiod). The lighting used was a combination of fluorescent and incandescent lights during the first 6 months of growth in a heated greenhouse.

At that time, it was also reported that experiments had been initiated at the Northern Forestry Centre (NoFC) during the late fall of 1983 to more

fully examine the phenomenon of early accelerated growth in conifers. Of major interest was the interaction of photoperiod with the three different types of supplemental lighting systems that were most available to greenhouse growers. This included the fluorescent plus incandescent combination used by Wheeler (1979) and those reported by Dymock and Wilson (1986).

This report will specifically concern itself with some of the results obtained to date for lodgepole pine, jack pine, white spruce, and black spruce. It will also address the costs, benefits, advantages, and disadvantages that are associated with the use of fluorescent lights (Fl), fluorescent plus incandescent lights (Fl + In), and high pressure sodium vapor lights (Na).

MATERIALS AND METHODS

Seedlings of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), white spruce (*Picea glauca* [Moench] Voss), jack pine (*Pinus banksiana* Lamb.), and black spruce (*Picea mariana* [Mill] B.S.P.) were grown under each of the experimental lighting systems (Fl, Fl + In, or Na) as shown in Figure 1. Seedlings were reared in peat moss in 5.4-L square plastic pots in heated greenhouses at NoFC using the rapid growth fertilizer regime of Carlson (1983). The technical information pertaining to each supplemental lighting system (Fig. 1) is shown in Table 1.

Two photoperiods were used throughout these studies. The first was the standard photoperiod used by research staff at NoFC, which consists of an the 18-h day and 6-h night. The second photoperiod was continuous light, or 24-h day. Each experiment was initiated during the late fall and ran for 32 weeks in the greenhouses. This was followed by a hardening-off period (Carlson 1983) that normally began in late May or early June of the following year, ran for 4-6 weeks, and was followed by outplanting of trees from all treatments in the NoFC nursery complex.

Prior to the start of the experiments, both the light quality and light quantity in each compartment under each of the respective lighting and photoperiod combinations was measured. This was accomplished using an LI-1800 Portable Spectroradiometer. The total spectrum for each system from 300 to 1100 nm was measured and recorded as shown in Figure 2. From these spectra the PPFD for each system was calculated (Table 1, Fig. 2). During each experiment the PPFD was monitored using an LI-185B Quantum/Radiometer/Photometer equipped with an LI-190SB Quantum Sensor. Irradiance (W/m^2) and illuminance (lux) were also measured using LI-200SB Pyranometer and LI-210SB Photometric Sensors, respectively. All light measurements were made well after dark, in the absence of any natural daylight or light from other interfering sources.

The standard bench size in these experiments was 5 m^2 for each supplemental lighting system (Fig. 1, Table 1). Each bench could hold 120 pots.

The PPFD for each lighting system was converted to the daily available supplemental PPFD ($mol \cdot m^{-2} \cdot d^{-1}$ (Table 1). From the technical data in Table 1 the power consumption per bench per day was then calculated, and the cost of electricity per bench per day was then calculated as shown (Table 1). For these calculations the peak power cost charged by Edmonton Power ($0.039/kW•h) was used to simplify the calculations.

Height measurements were made biweekly, usually from week 12 through to week 32. Stem diameter measurements were made at the beginning and end of each study. There were 24 trees per treatment in each case. Mean values were calculated, and the data were analyzed by one-way ANOVA followed by

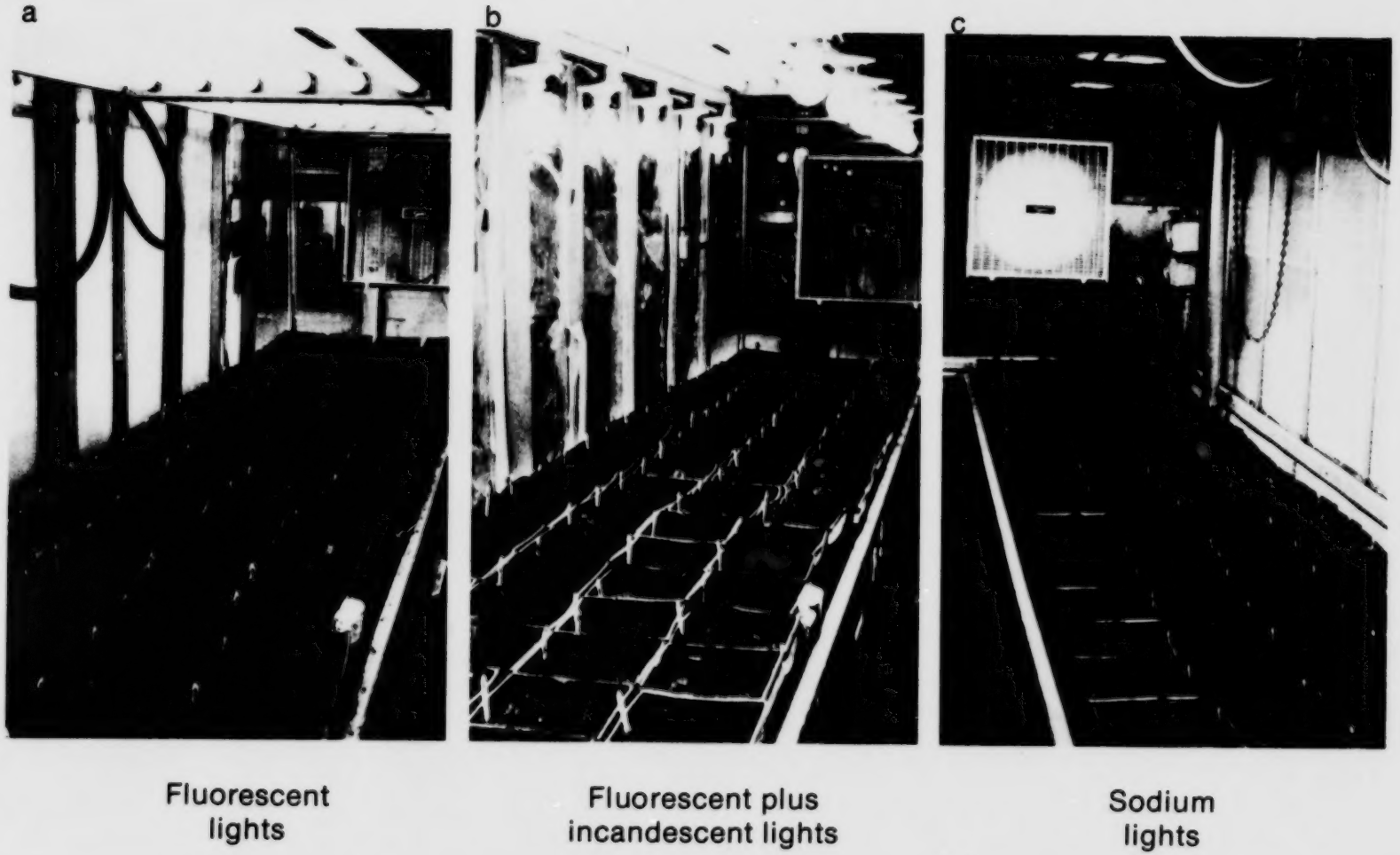

Figure 1. **Layout of each of the supplemental lighting systems shortly after the initiation of the experiment on black spruce.**

Greenhouse compartments were equipped with a) Fl, b) Fl + In, and c) Na lights in the configurations outlined in Table 1.

Table 1. Characteristics of the three types of supplemental lighting systems used throughout the studies on early, accelerated growth in conifers. Bench area = 5.0 m^2.

	Fluorescent lamps (Fl)	Fluorescent plus incandescent lamps (Fl + In)	High pressure sodium vapor lamps (Na)
Bulb type, output, and numbers	Cool white 45 W fluorescent 6 X F96T12/CW/HO 6 X F72T12/CW/HO	Cool white 45 W fluorescent 6 X F96T12/CW/HO 6 X F72T12/CW/HO plus 20 X 100 W incandescent	High pressure sodium 5 X 400 W
PPFD (PAR 400-700 nm) ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	59.6 ± 2.4	84.8 ± 2.4	214.4 ± 5.5
Daily available PPFD ($mol \cdot m^{-2} \cdot d^{-1}$)			
18-h day	3.86	5.50	13.89
24-h day	5.14	7.34	18.52
Power consumption (per bench per day)			
18-h day	9.72 kW	45.72 kW	36.0 kW
24-h day	12.96 kW	60.96 kW	48.0 kW
Cost of electricity (per bench per day)			
18-h day	$0.38	$1.78	$1.40
24-h day	$0.51	$2.38	$1.87
Influence on height (% of Fl as control)	100%	90-176%	136-230%
Influence on stem diameter (% of Fl as control)	100%	86-137%	182-325%
Heating costs	Minimal effect	Costs decreased	Costs decreased substantially
Seedling vigour/health	Least vigorous, increased pathological problems	Better than Fl, increased pathological problems	Very vigorous, few pathological problems

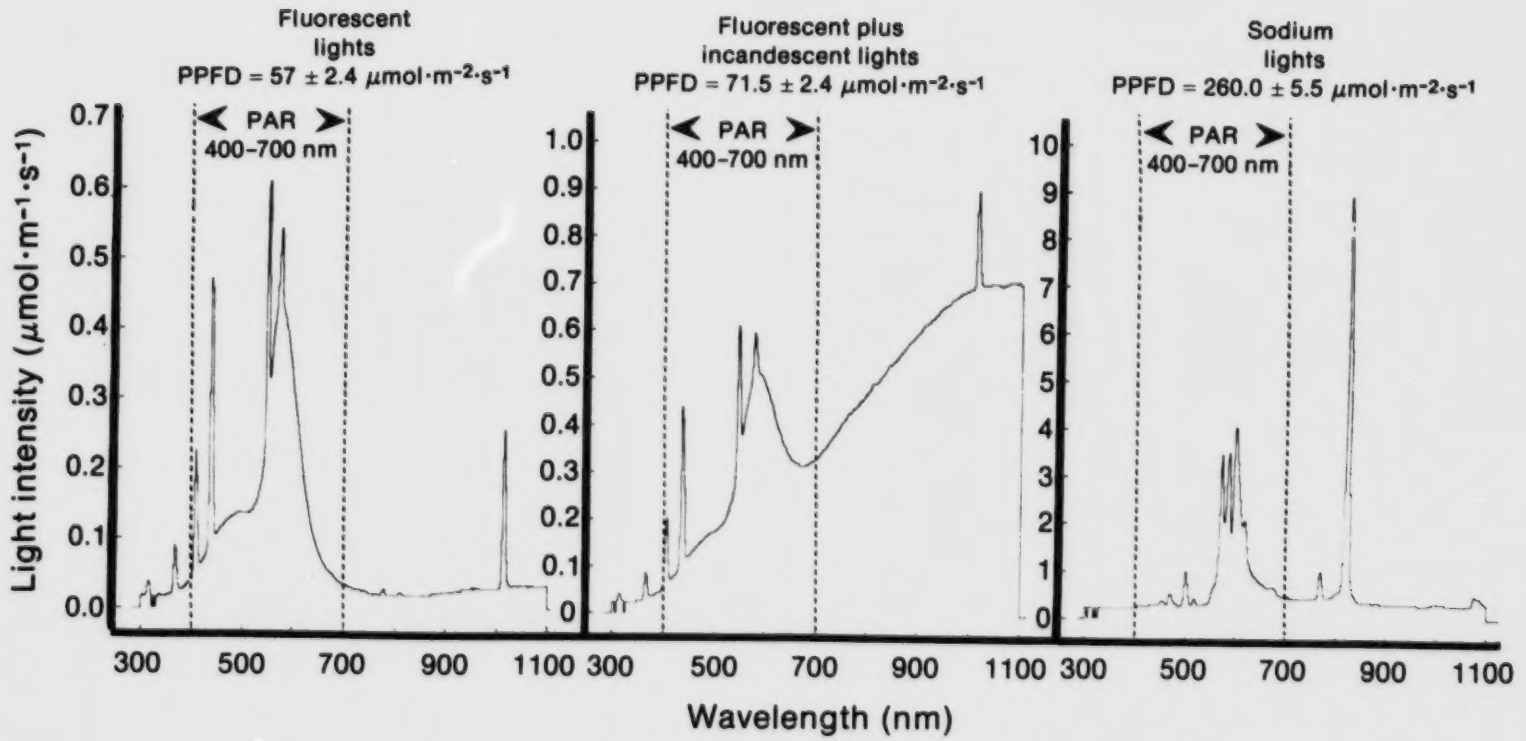

Figure 2. Comparison of the spectral distribution, photosynthetically active radiation (PAR) and photosynthetic photon flux densities (PPFD) of each of the supplemental lighting systems.

Spectrographs were obtained from each greenhouse compartment equipped with a) Fl, b) Fl + In, and c) Na lights as shown in Figure 1 and Table 1. The spectra shown are typical for each of the light sources employed. Spectra were recorded well after dark in the total absence of any other light sources. Measurements were taken 0.75 m below the fluorescent tube for Fl and Fl + In lights and 1.20 m below the bulb for Na lights.

Duncan's Multiple Range Test to show where significant qualitative differences exist between means for each parameter within a species.

RESULTS

Characteristics of Supplemental Lights

The spectral distributions and PPFD (Fig. 2) for each light source in Figure 1 show that major differences exist in light quality and quantity for each system. It is apparent, however, that Na lights provide the best levels of PPFD to supplement natural daylight. The sodium lights were 1.2 m above seedling tops; Fl and Fl + In lights were approximately 0.75 m above. At these distances, the distribution of supplemental light from each type was optimal and allowed for the maximum amount of exposure to natural daylight with the least amount of shading. To place any of the lighting systems closer to the seedlings resulted in overheating problems with the Na and Fl + In lights or too much shading from natural daylight for the Fl and Fl + In lights.

Data from Table 1 and Figure 2 indicate that Na lights provided 4.5 and 3.6 times more usable light (PPFD) than Fl and Fl + In lights, respectively. This is also reflected in the figures for daily available PPFD from supplemental sources (Table 1). It should be noted that seedlings under each of the light and photoperiod combinations received comparable levels of natural daylight between sunrise and sunset (data not shown). The supplemental lights were left on continuously during the daylight hours to provide the same minimum levels of PPFD for each of the treatments.

Height Growth

The influence of the light and photoperiod combinations on height growth of lodgepole pine can be seen in Figures 3a and 4a. Figure 3a shows the height growth of lodgepole pine from age 13 weeks to 31 weeks for each treatment. No significant difference ($P > 0.05$) exists in the height of lodgepole pine seedlings at 31 weeks between 18-h Na, 24-h Na, 18-h Fl + In, or 24-h Fl + In treatments. This can also be seen in Figure 4a, which is a photograph of the trees from each treatment that were closest to the mean height per treatment out of a total of 24 trees per treatment. Both Fl photoperiodic treatments (18- and 24-h) were significantly shorter ($P < 0.05$) than the other treatments. Obvious differences in vigor are apparent from Figure 4a.

Jack pine show a more diverse response to the light and photoperiod treatments in their height growth than do lodgepole pine, as shown in Figures 3a and b and 4a and b. The 18-h Na seedlings were significantly taller ($P < 0.05$) than the 24-h Fl + In seedlings after 32 weeks. The 24-h Fl + In seedlings were in turn significantly taller ($P < 0.05$) than either of the 24-h Na or 18-h Fl + In seedlings (Fig. 3b). As with lodgepole pine, both Fl treatments produced the shortest seedlings. Figure 4b shows clearly that the 18-h Na seedlings were the most vigorous and, as with lodgepole pine (Fig. 4a), had the best root development.

White spruce also shows quite diverse height growth responses to each of the light and photoperiod treatments (Figs. 3c, 4c). As with jack pine, and to a lesser extent (although not statistically significant, $P > 0.05$) with lodgepole pine, the 18-h Na white spruce seedlings achieved the greatest height growth, being significantly taller ($P < 0.05$) than the 24-h Na seedlings (Fig. 3c). These in turn were significantly taller ($P < 0.05$) than the 24-h Fl + In seedlings, but the 24-h Fl + In seedlings were not significantly taller ($P > 0.05$) than the 24-h Fl seedlings. No

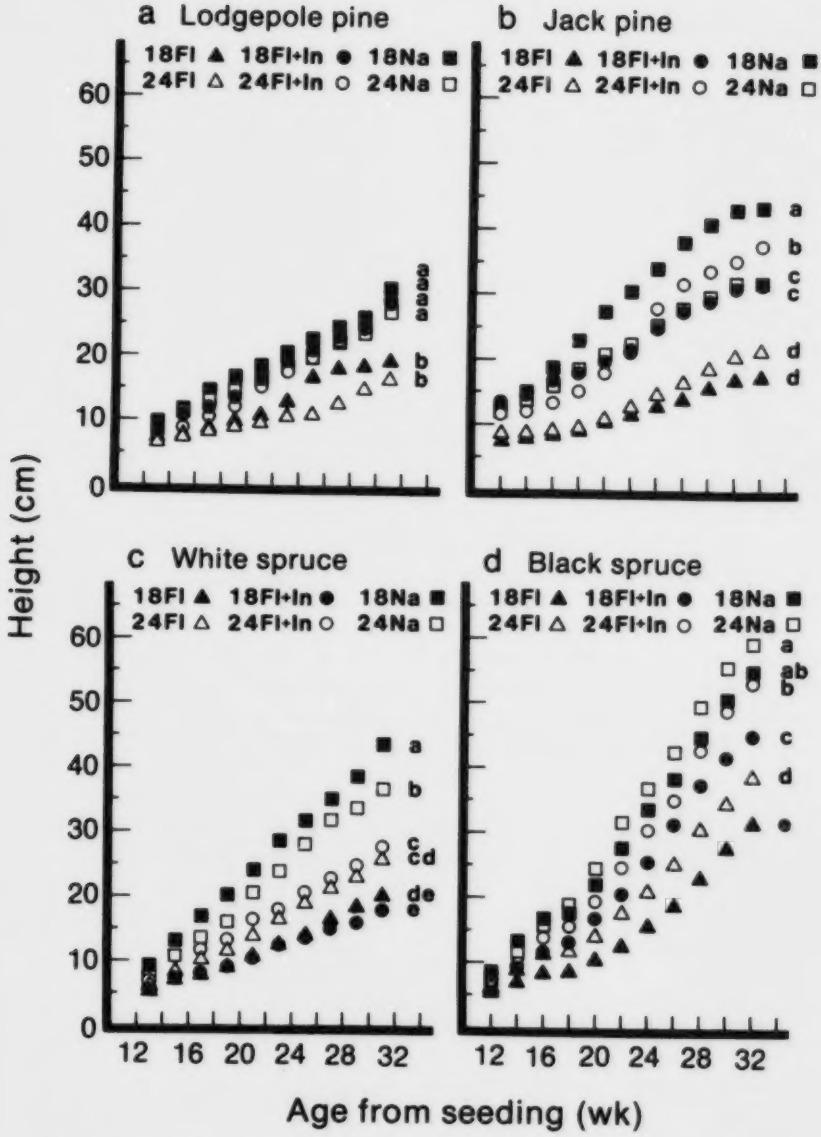

Figure 3. **Comparative height growth of lodgepole pine, jack pine, white spruce, and black spruce under each light and photoperiod treatment from the age of 12 weeks up to 32 weeks.**

Biweekly height measurements of seedlings were made starting 12-13 weeks after seeding through to the end of the rapid growth period for each species a) lodgepole pine, b) jack pine, c) white spruce, and d) black spruce. Each data point represents the mean value for 24 trees. Data were analyzed after week 31 or 32 by one-way ANOVA followed by Duncan's Multiple Range Test. Means for each species not followed by the same letter are significantly different ($P < 0.05$).

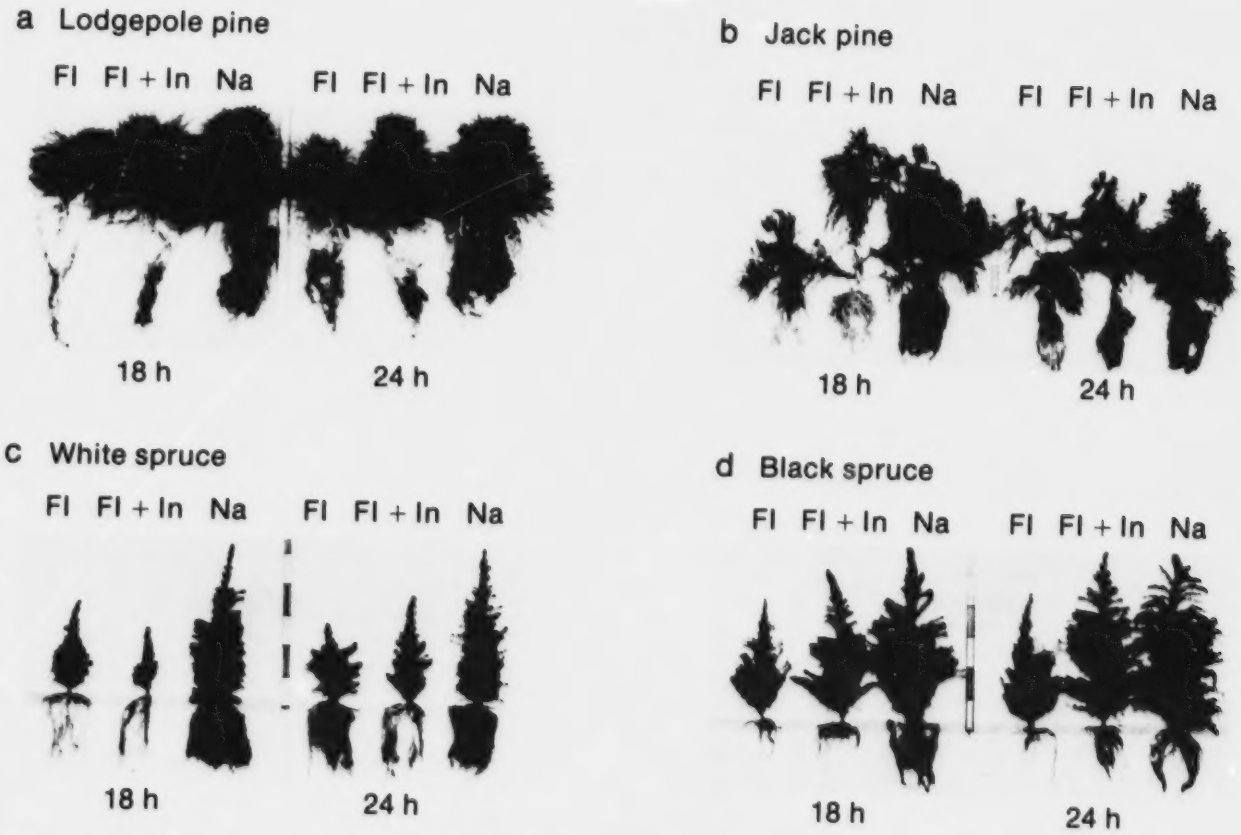
a Lodgepole pine
Fl Fl + In Na Fl Fl + In Na
18 h
24 h
b Jack pine
Fl Fl + In Na Fl Fl + In Na
18 h
24 h
c White spruce
Fl Fl + In Na Fl Fl + In Na
18 h
24 h
d Black spruce
Fl Fl + In Na Fl Fl + In Na
18 h
24 h

Figure 4. **Comparative morphology of lodgepole pine, jack pine, white spruce, and black spruce on completion of the rapid growth phase under each light and photoperiod treatment.**

The photographs of a) lodgepole pine, b) jack pine, c) white spruce, and d) black spruce were taken at the seedling age of 32 weeks. Each tree shown is the one that at that time was closest to the mean value for height growth out of 24 trees per treatment. The vertical line at the edge of the photograph for each species represents a scale of 225 cm. This easily facilitates relative comparisons of shoot and root morphologies of the seedlings grown under each light and photoperiod treatment.

significant differences ($P > 0.05$) in heights were noted between 24-h Fl and 18-h Fl seedlings or between 18-h Fl and 18-h Fl + In seedlings. It should be noted, however, that a 24-h photoperiod could improve height growth of white spruce seedlings if either Fl or Fl + In lighting systems were employed, but other problems could arise with respect to poor root growth and poor seedling vigor (Table 1), which can be observed in Figure 4c.

Black spruce seedlings showed the greatest height growth under the 24-h Na lights, but it was not significantly greater ($P > 0.05$) than was seen under the 18-h Na treatment (Figs. 3d, 4d). Black spruce seedlings under the 24-h Na lights were significantly taller ($P < 0.05$) than 24-h Fl + In seedlings, but there was no significant difference in height ($P > 0.05$) between 18-h Na and 24-h Fl + In seedlings. Each of the other three treatments (18-h Fl + In, 24-h Fl, and 18-h Fl) were significantly different ($P < 0.05$) from the other treatments and from each other (Fig. 3d). The results are corroborated in Figure 4d. As was seen with white spruce seedlings, the 24-h photoperiod resulted in significantly increased height growth ($P < 0.05$) of black spruce seedlings grown under Fl + In lights. This was also true for black spruce seedlings grown under Fl lights.

These results for height growth are confirmed with respect to height growth for each species when the final heights are plotted against the daily PPFD as shown in Figure 5. For each species the greatest height growth could be reached under 18-h Na lights, based on 13.89 mol PAR/m^2 of bench space per day. Above this level for jack pine and white spruce there were significant reductions ($P < 0.05$) in height growth under the 24-h Na lights. For lodgepole pine and black spruce there were no significant differences ($P > 0.05$) in height growth with 24-h Na lights.

Stem Diameter

Biweekly measurements of stem diameters were not carried out throughout the experiments due to the difficulties associated with reaching around vigorously growing trees that were spaced four deep on each bench. Pines during active leader elongation were very susceptible to physical damage. Initial and final stem diameters were measured, however.

Figure 5 shows the final stem diameter measurements plotted against the daily PPFD in the lower half of the figure. It is readily apparent that the best stem diameter growth was achieved under the 18-h Na lights for three of the species examined (lodgepole pine, jack pine, and white spruce). Photoperiod extension using Na lights from the 18-h day to a 24-h day resulted in significant reductions in stem diameter growth ($P < 0.05$) in these three cases. For black spruce, there was a marginally significant ($P < 0.05$) increase in stem diameter under 24-h Na lights over that achieved with the 18-h Na lights (Fig. 5). These results generally paralleled those seen for height growth in all four species.

Power Consumption and Electricity Costs

Data shown in Table 1 indicate that the Fl + In combination of lights was the largest consumer of power. Using the 18-h day, Fl + In lights consumed 4.7 and 1.3 times more power than did Fl and Na lights, respectively; Na lights consumed 3.7 times more power than Fl lights. Of primary consideration to the data on power consumption, however, is the usable light (PPFD) generated by each light source. Although Na lights used the second highest amounts of electricity, they generated 4.5 and 3.6 times more usable light (PPFD) than did the Fl + In and the Fl lights, respectively.

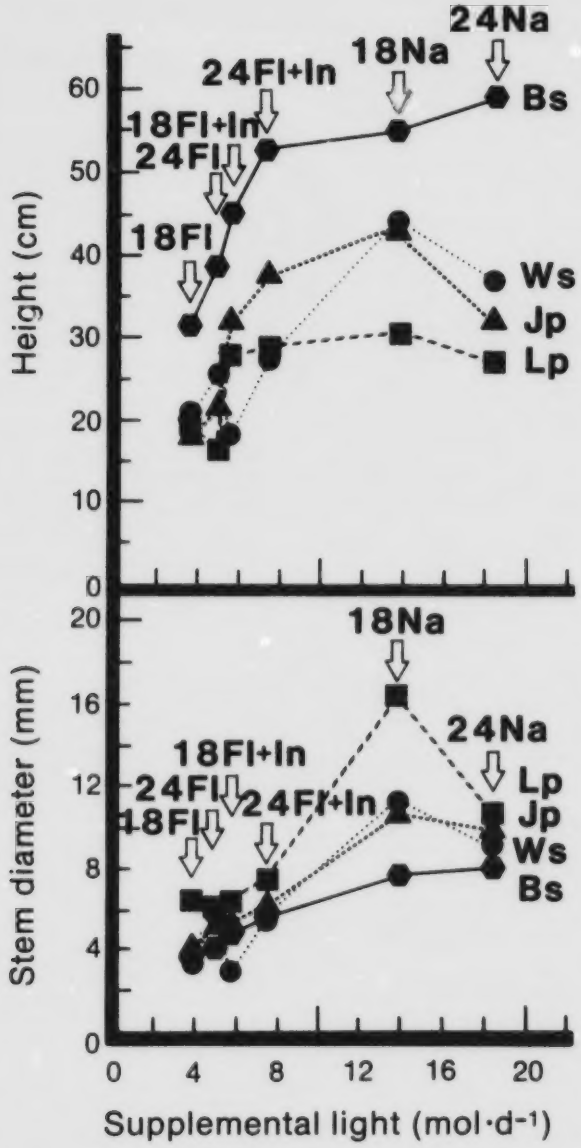

Figure 5. **Comparison of height and stem diameter with daily photosynthetic photon flux density (PPFD in mol·m^{-2}·d^{-1} of PAR, 400-700 nm) after the rapid growth phase for each light and photoperiod treatment.**

Data shown represents the mean values for 24 trees per treatment. Values for PPFD were taken from Table 1. The height values were those values shown at the end of the rapid growth phase in Figure 1. Stem diameters had been measured at the same time.

This resulted in significantly greater height and stem diameter growth for all four species. This is a direct result of more available (usable) photosynthetically active radiation being generated by the Na light sources (Table 1, Fig. 2).

Other Considerations

Both Na and Fl + In lights generate substantial amounts of heat energy in addition to the usable light (PPFD). It has been observed during the course of these studies over four winters that while the Na lights (and to a lesser extent the Fl + In lights) were on, the steam-heating systems in each of the compartments with these lights rarely came on. Only when the outdoor temperatures reached below -25°C, and under windy conditions, did the steam heating remain on constantly. Although it was not actually quantified, the excess heat generated by the Na lights substantially reduced greenhouse heating costs. This was particularly evident after internal fans were installed to circulate this excess heat.

This result is not particularly surprising when one considers that Na lights are far more efficient than the other systems at converting electrical energy to light energy. Sodium lights are 25% efficient, whereas incandescent lights are no more than 6.5% efficient (Stolze et al. 1985), and Fl lights are even less efficient. This is corroborated by the PPFD and power consumption data from Table 1.

Seedling vigour was greatest under 18-h Na lights, as was seen for each species in Figure 4. Fewer pathological problems (insect or disease) were seen on seedlings grown under 18-h Na lights. Some mortality occurred during the course of these studies, but it was mostly under continuous daylight (24-h day) conditions using Fl and Fl + In lights (data not shown).

Outplanting survival has been extremely high for most treatments. During the winter of 1984-85 only one lodgepole pine mortality occurred out of 300 trees. There have been equally few mortalities among outplanted white spruce and jack pine that could be attributed to treatment effects (data not shown). Black spruce were only outplanted in July 1987 and have yet to experience their first winter.

DISCUSSION AND CONCLUSIONS

It is apparent from the data presented that the most effective lights for use in greenhouses to rear conifers are high pressure sodium vapor (Na) lights. From the results presented, Na lights using the 18-h day and 6-h night photoperiod provided the best growth in the four species examined. These results confirm those in the earlier report of Dymock and Wilson (1986). The results presented in this report were for seedlings reared in 5.4-L pots, while those of Dymock and Wilson (1986) were for seedlings reared in Spencer-Lemaire Super 45s.

In other studies (Dymock and Dendwick 1987; Edwards 1987; Edwards 1986) where seedlings have been reared in the NoFC greenhouses in Spencer-Lemaire 5s or Ferdinands (Spencer-Lemaire Industries, Edmonton, Alberta) or Styro 20 containers (Beaver Plastics, Edmonton, Alberta), we have achieved comparable seedling heights for each species (Fig. 3) during the equivalent 14-16 week rapid growth stage in the greenhouse. The results reported for pots and larger containers have thus been readily translated to the smaller volume container situation.

The increased efficiency of Na lights as measured by daily available PPFD and the growth rates achieved more than compensate for increased electrical costs. When capital and

operating costs are averaged out over the lifetime of a greenhouse operation, the cost of power per seedling is minor when compared to all other operating costs (Stolze et al. 1985). The end result is a superior seedling ready for outplanting.

It is apparent that the spectral balance of the Na lights (Table 1, Figs. 2, 4) exerts very significant morphogenetic effects on the seedlings in each of the species that were examined, corroborating previous findings of Vince-Prue and Canham (1983). It is also apparent from the results that light intensity can also have very significant morphogenetic effects (Fig. 4) and that the duration of exposure to supplemental Na lighting can reach an optimum (Fig. 5). It would appear from Figure 5 that saturation of the photosynthetic apparatus can be reached for these species, as reflected by the levelling off of both height and stem diameter growth. This apparently occurs when the total daily available PPFD surpasses levels achieved using 18-h Na lights. This, then, is a point that must be kept in mind when planning what type of supplemental lights will be used in a greenhouse environment. This consideration, as well as the maximum light intensity incident per unit area per unit time (Kramer and Kozlowski 1979; Smith 1982) will have a significant impact on the results expected.

Supplemental lighting systems that use Na lights under the 18-h day and 6-h night photoperiod combined with proven container production procedures and schedules (Carlson 1983) should yield greatly increased benefits through the production of superior planting stock.

When this is combined with the potential benefits of indoor hardening procedures such as the Extended Greenhouse Culture Method (Colombo et al. 1984), proven methods for monitoring the development of dormancy and cold hardiness (Colombo and Cameron 1986; Dymock and Dendwick 1987), and the development of efficient cold storage facilities for container stock, it should be possible to move to year-round container stock production. These steps could greatly reduce production times for high-quality seedlings for outplanting. Container-grown stock that is equivalent in size to 2-0 and 3-0 bare-root stock (or to equivalent-sized container transplants) could be produced continuously by production greenhouses throughout the year, with at least two fully developed crops possible per year. This would be based on a 14-week rapid growth phase followed by 10 weeks to completely harden-off each crop.

This system would partially meet the increasing demands for larger numbers of high-quality seedlings for reforestation purposes in a much shorter time frame.

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CALIBRATION OF NUTRIENT PRESCRIPTIONS FOR BARE-ROOT NURSERIES

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INTRODUCTION

Nursery production of bare-root stock, like agricultural production of food and fibre crops, depends on the input of nutrients to the soil (mostly as fertilizers) to sustain successive crop growth. As in agronomy, soil samples are chemically tested and, based on the results, prescriptions are made for the application of fertilizer nutrients, mostly nitrogen (N), phosphorus (P), and potassium (K). How are the prescriptions derived? They are based on prior knowledge of the effect of known amounts of fertilizer on plant growth, and the expression of such a relationship in graphical or other forms is known as calibration. This paper shows, with examples, how to determine nutrient requirements of a crop and how fertilizer prescriptions are derived.

CALIBRATION

As soon as a nursery is developed, one of the first questions asked by the nurseryman concerns what types and amounts of fertilizers should be applied in order to obtain a desired crop quality. To answer these questions, it is necessary to proceed systematically, as follows:

1. Draw up specifications for morphological characteristics such as height, root-collar diameter, seedling dry weight, and shoot: root ratio.

2. To determine nutrient requirements of a crop (in terms of N, P, and K), lay out a fertilizer experiment that is well replicated.

3. Apply a series of dosages of each nutrient, singly or in combination, to plots in which the seedlings are grown. During the cropping period, water and weed according to the routine used for the rest of the nursery.

4. At the end of the cropping period, measure the growth characteristics, e.g., height, root-collar diameter, and seedling dry weight.

5. Determine the optimum level of fertilization or nutrient requirement by plotting the response of a specific characteristic to various levels of nutrients.

6. Verify the optimum level of fertilization in subsequent crops by applying levels that are more and less than the optimum and noting the response in growth. Confirmation of the optimum level indicates that the seedbed is calibrated for requirement of a particular nutrient.

7. In succeeding crops, it is necessary only to develop a fertilizer prescription or recommendation. The prescription is the difference between the nutrient requirement and the amount of plant-available nutrients already in the soil. This is determined by soil testing.

CALCULATIONS

To determine the amount of nutrients to be added to each plot during the field experiment, assume that the size of each plot is 1 × 1 m or 1 m^2. As 1 ha = 10 000 m^2, each plot is

0.0001 ha. Assume that we would like to add nutrients at the following rates: 0, 28, 56, 112, 168, and, 224 kg/ha. Then each plot would require 0, 2.8, 5.6, 11.2, 16.8, and 22.4 g/plot.

Nitrogen

If N is supplied by ammonium nitrate (34-0-0), for example, the amount of fertilizer required per plot is determined by multiplying g/plot of N by the factor 100/34, or 2.94. Therefore, 0, 2.8, 5.6, 11.2, 16.8, and 22.4 g/plot of N equals 0, 8.2, 16.5, 33.0, 49.5, and 66.0 g/plot of N fertilizer.

Phosphorus

If P is supplied by concentrated superphosphate (0-45-0), the amount of P fertilizer required per plot is determined by multiplying g/plot of P by the factor 100/19.8, or 5.05. Therefore, 0, 2.8, 5.6, 11.2, 16.8, and 22.4 g/plot of P equals 0, 14.1, 28.3, 56.6, 84.9, and 113.2 g/plot of P fertilizer.

NOTE: Fertilizer with the formulation 0-45-0 indicates the presence of 45% P_2O_5 and is equivalent to 45 × 0.44 or 19.8% P.

Potassium

If K is supplied by potassium sulfate (0-0-50), the amount of K fertilizer required per plot is determined by multiplying g/plot of K by the factor 100/41.5, or 2.41. Therefore, 0, 2.8, 5.6, 11.2, 16.8, and 22.4 g/plot of K equals 0, 6.7, 13.5, 27.0, 40.5, and 54.0 g/plot of K fertilizer.

NOTE: Fertilizer with the formulation 0-0-50 indicates 50% K_2O and is equivalent to 50 × 0.83 or 41.5% K.

OPTIMUM LEVEL OF FERTILIZATION

Determine the mean height, root-collar diameter, and seedling dry weight associated with each level of fertilization.

Construct a curve to show the relationship between fertilization and each characteristic. The graph for seedling dry weight, for example, may look like that in Figure 1.

The graph shows that the growth associated with the application of N at 112 kg/ha is significantly greater than that at 56 kg/ha, but it is not inferior to growth obtained with the application of 168 kg/ha. Growth began to decline at 224 kg/ha, probably indicating some level of toxicity. In this example, fertilization at 112 kg/ha is optimum.

In cases where the differences in response to fertilization are not as clear, a statistical analysis of the data is made to gain some inference about the significance of the differences between means. The aim is to identify the minimum input that produces acceptable stock, morphologically and physiologically.

Repeated experiments may be conducted to either confirm the relationship or to test intermediate levels of fertilizers.

Having established the optimum level of fertilization, it is necessary in subsequent years to determine only the level of available nutrients in the soil (through chemical soil testing), and to make up, through fertilization, the difference between the amount that is present and the amount that is required. It is on this basis that fertilizer recommendations are developed. Let us see how the calculations for this are done.

FERTILIZER RECOMMENDATIONS

Assume that the optimum level for a nutrient is 112 kg/ha. If soil testing indicates that the amount of available nutrient is only 30 kg/ha,

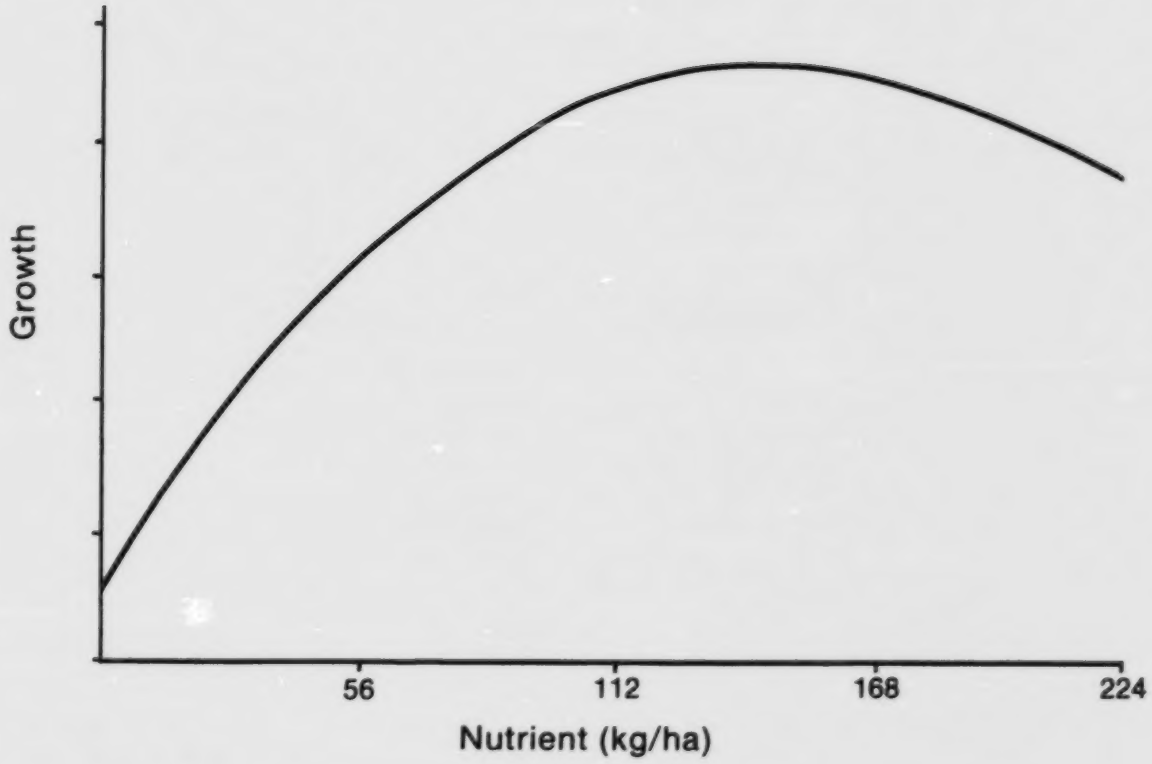

Figure 1. Growth response to nutrient application.

it means that a total of 82 kg/ha is required from fertilization.

If N is the nutrient and ammonium nitrate (34-0-0) is used to supply N, the quantity of fertilizer required is (82 × 100/34) kg/ha, or 241 kg/ha.

If P is the nutrient and concentrated superphosphate (0-45-0) is used to supply P, the quantity of fertilizer required is (82 × 100/19.8) kg/ha, or 414 kg/ha (45% P_2O_5 is equivalent to 19.8% P).

If K is the nutrient and potassium sulfate (0-0-50) is used to supply K, the amount of fertilizer required is (82 × 100/41.5) kg/ha, or 198 kg/ha (50% K_2O is equivalent to 41.5% K).

SOIL TEST RESULTS

There are numerous soil testing procedures for different elements and for different soils. The essential point to bear in mind is that the method used by any laboratory should produce results that are highly correlated with plant growth and nutrient uptake. If this condition is met, the results will be valid for the calculation of fertilizer recommendations as outlined above.

The expression of soil test results should not present a problem. If the unit of expression is kg/ha, no conversion is necessary. If the unit is given in ppm (parts per million), mg/kg, percent, or lb./acre, conversion to kg/ha is required. Conversion factors are as follows:

1%	=	10 000 ppm
mg/kg	=	ppm
ppm × 2	=	lb./acre
lb./acre × 1.12	=	kg/ha

SUMMARY

Calibration of nursery soil is the determination of the level of nutrient that is required to produce a crop with desired specifications. It initially consists of soil testing and a fertilizer trial to develop the nutrient requirement. Checks are subsequently made to confirm the requirement. Fertilizer recommendations are made annually to make up the deficit between the requirement and the available nutrients in the soil.

RECOMMENDATIONS

1. Develop morphological and physiological specifications for the seedlings to be produced.

2. Do soil testing of the nursery beds.

3. Apply different levels of fertilizer in a replicated experiment.

4. Determine the minimum level of a nutrient that produces the most suitable seedlings in terms of the desired specifications.

5. In subsequent crops, add enough fertilizer to bring soil nutrient level to that found in Step 4. The minimum level of soil nutrient that is associated with the most suitable plant growth and nutrient uptake is the plant requirement. Standards for foliar concentration of nutrients should be met.

6. Always perform random checks in successive crops by applying, to selected plots, levels of fertilizers that are either more or less than the plant requirement. If growth performance remains constant or declines with more fertilizer and also declines with less, the plant requirement in Step 5 is confirmed and the soil is calibrated for that species. Soil fertility standards are essential features of any bare-root nursery.

7. If there are no major changes in soil management (e.g., removal of

top soil, pipeline placement) and if the required levels of pH and organic matter are met, soil productivity can be maintained through fine tuning the system, as in Step 6.

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CANADIAN FOREST NURSERY WEED MANAGEMENT ASSOCIATION

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The decision to form an ongoing weed management committee was made following the Weed Control in Tree Nurseries Workshop held at Indian Head in 1984. This committee has survived and expanded and is now called the Canadian Forest Nursery Weed Management Association. Since that inaugural meeting in 1984, there have been annual workshops held in Fredericton, New Brunswick, Abbotsford, British Columbia, and Longueuil, Quebec. Hadashville, Manitoba, is the tentative location for the 1988 workshop.

The objectives of the association as outlined in the constitution are 1) to encourage a wider understanding of the problems of weed control in forest and shelterbelt nurseries, with particular emphasis on chemical weed control; 2) to advance the members in their knowledge of weed science and chemical weed control; 3) to promote public interest in and knowledge of sound forest and shelterbelt nursery weed control practices; 4) to initiate, design, plan, develop, and conduct national nursery research trials on herbicides that are promising for weed control in forest and shelterbelt nurseries so that sufficient data might be collected to allow for registration of these herbicides in Canada; and 5) to provide technical information to nursery personnel regarding wise management of weeds in nurseries.

The association's council has eight members. Richard Cameron and Wendy Kozmak, Manitoba Natural Resources, are Chairman and Secretary-Treasurer, respectively, with Jean Paul Campagna, Quebec Ministry of Energy and Resources, serving as Past-chairman. There are five regional representatives: Newfoundland and the Maritimes are represented by Len Lanteigne, Forestry Canada; Quebec by Jean Paul Campagna; Ontario by Rob Geier, Ontario Ministry of Natural Resources; the prairie provinces by Lyle Alspach, Agriculture Canada; and British Columbia by John Maxwell, B.C. Ministry of Forests.

The regional representatives are responsible for dissemination of information to members within their region and for identifying regional concerns and issues to the Chairman. Consequently, the regional representatives serve as the local nursery's link to the association.

The association has concentrated on oxyfluorfen trials, for both bare-root and container production of conifers. In 1987, lactofen and ethalfluralin were also included for testing. Trials of this nature are conducted to generate regional data in support of an application for minor-use registration. Herbicides must, however, be registered for some other use before a minor-use registration can be granted.

Oxyfluorfen has had a temporary, restricted registration since 1985 for use on onion crops. Full registration for oxyfluorfen is dependent upon the manufacturer, Rohm and Haas Company, generating the additional toxicology data necessary to satisfy the needs of Health and Welfare Canada. If accomplished, this will allow for the consideration of applications for minor-use registration. Such minor-use registrations would be welcomed by forest and shelterbelt nurseries alike.

Chemical company representatives present at the workshop in Longueuil

praised the association's coordinated approach to herbicide trials. The results from trials involving the same treatments and tested in several regions of Canada provide considerable data that can be used to support proposals for herbicide registration.

Researchers involved in herbicide testing should maintain an open line of communication with chemical manufacturers. Chemical companies' plans for development of a product are critical. If they do not intend to continue further development of a chemical, there is no point in including it in future trials.

In addition to keeping in contact with chemical companies, it is useful to have access to general pesticide information. Information concerning registration, safety, label instructions, and other issues regarding pesticide use can be obtained by calling the National Pesticides Call Line toll-free at 1-800-267-6315.

In conclusion, it can be safely stated that the Canadian Forest Nursery Weed Management Association has a definite function, and through the herbicide research activities that it organizes and promotes it can be a positive factor in the minor-use registration of herbicides for use in forest and shelterbelt nurseries.

OXYFLUORFEN TRIALS AT PRINCE ALBERT FOREST NURSERY

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INTRODUCTION

Saskatchewan Parks, Recreation and Culture agreed to participate in a countrywide trial of the herbicide Goal (oxyfluorfen) to determine its efficacy in controlling weeds and to provide supporting data for its registration for forest nursery use. Due to the demands of the experimental design and the amount of labor required to collect data, the decision was made to participate with one experiment only at the Prince Albert Nursery. The trial was conducted on a rising 1-0 white spruce (*Picea glauca*) field in 1986. For 1987 the trial was done on rising 2-0 white spruce in a different location. A sample of the chemical was supplied by the Rohm and Haas Canada Ltd. The trial outline, experimental design criteria, and treatment plan were written by Dr. C.G. Waywell and R.L. Geier, both of the Ontario Ministry of Natural Resources.

Prince Albert Nursery has a productive area of 120 acres on 480 acres. The area was once a farm and as a result has a good variety of common weeds. The nursery has an annual production of five million bare-root seedlings. Most weed control is now accomplished by manual labor, which accounts for a significant amount of our costs for growing the bare-root stock. The consideration of the high cost of manual weeding encouraged our participation in the Goal trial.

In order to evaluate the herbicide over all age classes and species it is the intent of the province to proceed with testing of jack pine (*Pinus banksiana*) as well as white spruce from 1-year-old stock to lifting as 2- or 3-year-old stock.

TRIAL LAYOUT

A recently seeded field was chosen to set up the experiment. The field was level, and the seedbeds (blocks) were not adjacent to irrigation lines or shelterbelts. The field had been prepared in the normal way the previous fall with the incorporation of peat moss and an application of Basamid (Dazomet). The seeding was conducted using a Love-Oyjord seven-drill seeder, after which a layer of hydromulch was applied. The field was irrigated three times a day.

The trial was replicated five times with the block treatments being placed along the length of the block (bed). The bed width was 1.27 m, and plot length was 3 m with 50-cm buffers on either end. All blocks were marked to prevent accidental weeding. Plot stakes were painted white for control, red for 0.25 kg/ha a.i. (active ingredient), blue for 0.50 kg/ha a.i. (active ingredient), and silver for 1.0 kg/ha a.i.

1986 TRIAL

Three applications at the three different concentrations were made during the experiment. The first application (June 13) was made as a preemergent, 1 week after seeding. The second application (June 27) was made as a postemergent; germination had taken place, seed coats were being shed, and the weeds were at the two-

to four-leaf stage. The final application (July 21) was made 6 weeks after the first, when weeds were rapidly growing in flower and covering most of the plots to be treated.

In order to determine the efficacy of the oxyfluorfen applications, a weed count was conducted at the end of August on each plot. The weed count included weed identification and fresh weed weight. Two quadrats of 0.25 m^2 were taken from each plot.

Results

Excellent results were achieved with the preemergent and the initial postemergent applications; good results were obtained from the second postemergent treatment (Table 1). Statistical differences were detected with all treatments between the unweeded control and the oxyfluorfen applications.

The preemergent application controlled weeds for 7 weeks. After this point woody weeds such as willow (*Salix*) and red elder (*Sambucus pubens*) appeared in the seedbeds; some weeds also appeared from adjacent seedbeds, which acted as buffers between blocks. Where willow received direct contact with the spray, it was controlled. No control was achieved with oxyfluorfen as a preemergent. Apparently the red elder had not germinated when the last application was made; the chemical did not affect its growth.

Complete control was given over the following weeds with the preemergent and initial postemergent applications: portulaca or purslane (*Portulaca oleracea*), lamb's quarters (*Chenopodium album*), shepherd's-purse (*Capsella bursa-pastoris*), stinkweed (*Thlaspi arvense*), perennial sow thistle (*Sonchus arvensis*), yellow sweet clover (*Melilotus officinalis*), red-root pigweed (*Amaranthus retroflexus*), tartary buckwheat (*Fagopyrum tataricum*), and common groundsel (*Senecio vulgaris*).

Grasses appeared in one plot only in one block so that no assessment could be made whether the oxyfluorfen actually controlled grass species. The plot was an unweeded check.

Crop tolerance was assessed on September 23, 1986. There were no visual differences between the handweeded checks and the treatments at any concentration or time of application.

Conclusions

The oxyfluorfen was most effective as a preemergent or an early postemergent herbicide. Efficacy was reduced at the 0.25 kg/ha second application, although control was still significant over the unweeded check. The degree of control achieved by the first two applications would be sufficient to achieve significant weed control until the end of the season. Common purslane was completely controlled with the preemergent and the first postemergent applications. This weed has been the most serious pest at Prince Albert Nursery. The labor component to control this weed probably represents 50% or more of the total weeding costs. If this chemical is registered for nursery use it will mean a substantial saving in both personnel and dollar terms.

The degree of control achieved with the second postemergent application was satisfactory, but it should not be used as a guideline for future late applications. The late application should be avoided; the plants at this stage are in flower, and by the time the chemical restricts weed growth or causes mortality, seeds have been shed and the weed problem is maintained for the following year. It would be more appropriate to hand weed the fields to achieve at least partial control.

Table 1. Weed control with oxyfluorfen applied at three rates at three intervals on bed-sown white spruce[a]

	Rate (kg/ha)	Fresh weight of weeds (g/m^2)	Weed control[b]
Hand weed check	-	-	9.0 a[c]
Unweeded check	-	1617.1 c	0.0 c
Preemergence	0.25	12.1 a	6.8 ab
	0.5	14.2 a	7.6 ab
	1.0	3.3 a	8.3 ab
First postemergence	0.25	15.6 a	8.1 ab
	0.5	5.1 a	8.5 ab
	1.0	1.0 a	8.7 a
Second postemergence	0.25	301.1 b	4.3 bc
	0.5	52.0 a	7.3 ab
	1.0	25.4 a	8.0 ab

[a] Data analysis was performed by personnel at the PFRA Shelterbelt Centre, Indian Head, Saskatchewan. Results are means of five replications.

[b] 0 = no control; 9 = complete control.

[c] Means in the same column followed by the same letter are not significantly different ($p < 0.05$) according to Student-Newman-Keuls' test. A $\sqrt{x + 1}$ transformation of the data was conducted prior to analysis.

1987 TRIAL

The oxyfluorfen was applied to rising 2-0 white spruce; the first application was in May, and the second and third applications were in June. Weed assessment including counting and weighing was completed during the last week of August. The experiment appeared to be less successful than the 1986 trial. The weed assessment was conducted late in the season; however, throughout the experiment it was noted that less control was achieved at all stages, unlike the 1986 experiment.

The following weeds were killed: narrow-leaved hawk's beard (*Crepis tectorum*), portulaca, common groundsel, shepherd's-purse, and lamb's quarters. These weeds were killed on spray contact: kochia (*Kochia scoparia*) and tansy mustard (*Descurainia pinnata* (Walt) Britt. var. *brachycarpa*). Sow thistle was controlled in the preemergent stage at the first application, stopped growing when sprayed directly, but recovered.

Other weeds that were present and not controlled were fireweed (*Epilobium angustifolium*) and willow. The weeds that were controlled but not killed were sow thistle, Russian knapweed (*Centaurea repens*), and dandelion (*Taraxacum officinale*).

Grasses that were present were not controlled in any way and include foxtail (*Hordeum jubatum*), witch grass

(*Panicum capillare*), red top grass (*Agrostis alba*), and nut sedge (*Carex brunnescens* Carey).

CONIFER TOLERANCE

The 1.0 kg/ha a.i. application has caused needle twisting on the second and third applications. There was no apparent mortality in the seedbeds from the oxyfluorfen treatments. Experiments with this chemical and others will continue in future years.

HERBICIDE PROGRAM AT PINELAND PROVINCIAL FOREST NURSERY

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INTRODUCTION

The Pineland Provincial Forest Nursery has over 14 ha of fields in seedling production. Of these, 52% are in seedbeds, and the remaining 48% are in transplants. In 1986, costs for hand weeding came to over $62,000. To reduce costs, the decision was made to implement an extensive herbicide program for the 1987 season.

MATERIALS AND METHODS

Over the 1986-87 winter, a new boom sprayer complete with computerized Dickey-John controller was purchased. In addition to this, the nursery already has a Myers boom sprayer, a wick applicator for Roundup, and a nursery-built in-row/pathway sprayer. Supplies of herbicides that have been accepted as safe for use over conifer seedlings were purchased. These included Enide, Dacthal, Gesagard, Amitrol, Devrinol, Simazine, Varsol Oil, Roundup, and Velpar. A small amount of Goal was also purchased for trial purposes.

In April, a plan was made for each field based on species and type and age of crop. Unfortunately, the sprayer, which was to be delivered by March 31, did not arrive until May. This caused two major problems: seedlings had started their period of active growth, so the types of herbicides that could be used were limited, and the weeds had already reached a size too large to be effectively controlled by herbicides. As a result, a major hand-weeding operation was required to clean up the fields. Once the first application of preemergent herbicides was made, postemergent herbicides were used as required to catch any escapes, and booster applications of preemergents were applied 6-8 weeks after initial applications. Over the summer, as manpower was available, hand weeders cleaned up the fields.

Control plots were established to determine the effectiveness of the herbicides. The plots were assessed 6 weeks after spraying.

RESULTS AND DISCUSSION

Table 1 shows the results from assessments of the spray and control plots. Applications of hexazinone over red pine and oxyfluorfen over jack pine gave excellent weed control. The diphenamid/chlorthal dimethyl tank mix only gave reasonably good control of broadleaf weeds and poor grass control. Results from plots treated with a simazine/napropamide tank mix also show poor weed control, although this is probably a result of the application being made at the booster rate (half the usual rate) because of previous applications of diphenamid/chlorthal dimethyl.

Plots were not established to check the efficacy of postemergent herbicides. In general, Amitrol applications were quite effective. Herbicidal mineral oil applications did not provide effective control, but purchase of a different formulation next year may correct this. Hexazinone applications provided very good control.

Table 1. Results of herbicide trials

Herbicide	Rate (kg/ha active ingredient)	No. of plots[a]	Average broadleaf weed count	Average broadleaf weed wt. (g)	Average grass weed count	Average grass weed wt. (g)
Diphenamid (Enide), chlorthal dimethyl (Dacthal)	4/5	11	3	10	19	4
Control[b]	0	11	9	24	40	6
Hexazinone (Velpar)	0.25	3	1	1	0	0
Control	0	3	17	2	-[c]	105
Simazine, napropamide (Devrinol)	0.5/2.25	2	2	8	20	3
Control	0	2	0	0	31	5
Oxyfluorfen (Goal)	0.5	1	0	0	2	0.125
Control	0	1	50	66	1	0.098

[a] Each plot was 1 m X 1.07 m (width of bed).
[b] Control plots received no herbicide treatment.
[c] Too many plants to count.

The effect of the herbicide program on the amount of labor required for hand weeding is shown in Table 2. After mid-June, when the first round of herbicide applications was completed, the amount of labor required for hand weeding dropped significantly.

CONCLUSION

The herbicide program, even with a slow start, did reduce the cost of hand weeding by about $17,000. Through experience and future participation in herbicide trials to test promising new herbicides and to refine application rates to fit specific weather, soil, and weed conditions at Pineland, we can look to increased efficiency in our herbicide program.

Table 2. Hand weeding summary

Month	Type	Hectares[a]	Hours	Hours/hectare
May	Overall	12.93	2645	204
	Transplants	4.36	985	226
	Seedbeds	8.57	1660	194
June	Overall	13.5	1231	92
	Transplants	4.36	658	151
	Seedbeds	9.14	573	63
July	Overall	14.3	370	26
	Transplants	6.65	36	5
	Seedbeds	7.67	334	44
August	Overall	14.8	240	16
	Transplants	7.13	82	12
	Seedbeds	7.67	158	21

[a] Based on bed area only; does not include pathways or headlands.

COLD STORAGE OF CONIFER SEEDLINGS IN BRITISH COLUMBIA

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The aim of the British Columbia Ministry of Forests is to plant about 200 million conifer seedlings annually; therefore, cold storage is an integral part of the provincial silviculture program. It involves some form of cold storage for about 155 million container and 45 million bare-root seedlings. About 60 million container seedlings are lifted and shipped during the summer months, and a small amount are planted in the fall. The remainder are lifted and stored over winter for the spring and early summer planting programs. As a result, a cold storage capacity for about 135 million seedlings is essential. The budget for stock production exceeds $30 million and includes provincial government, company, and private nurseries, as well as cold storage and transportation. The two types of cold storage programs that have to be considered are the winter and summer-fall ones.

THE WINTER LIFT AND COLD STORAGE PROGRAM

The winter lift starts in late October and continues through until the middle of April. The timing depends on the location of the nurseries and the species and type of stock being grown. The timing of the early winter lift is determined by various methods and tests that evaluate frost hardiness and dormancy. The goal is to ensure that stock is lifted and stored at the time that it has maximum vigor and is able to maintain this during storage. Long-term storage is now the normal practice in British Columbia and may last up to 8 months.

Dormancy induction is now a standard operational practice in some container nurseries. Cold hardiness and bud development may be induced by shortening the days. In Ontario (Colombo et al. 1981) the cold hardiness of black spruce was increased by exposing them to 8-hour photoperiods for 8 weeks. There are variations in the methods of dormancy induction and this often varies with the stock species being treated (Rosvall-Ahnebrink 1981). Blackout systems are being used in private and provincial government nurseries with some success. In bare-root, the mid-summer applications of nitrogen are stopped by the middle of July, and the heat protection irrigation ceases just prior to that. Stock is only irrigated when it is necessary. Although potash and phosphate may be applied during this period, nitrogen is not normally applied again until early September.

In the past, stock was considered dormant when the buds were formed on the terminals and was ready to lift when the roots ceased to grow. Today, a large percentage of the seedlings are grown in the southern areas of the province for planting in the northern regions and high elevations; therefore, new methods of establishing the most suitable times to lift stock for storage became essential. Researchers have now provided us with more-precise methods of establishing lifting windows. Cold-hardiness testing (Simpson 1985) is the method that is used in British Columbia. This involves freezing the sample to -18°C and then determining the average foliage mortality in the sample. The -18°C was chosen because research indicated that it was the temperature at which

seedlings with LT 50 values seemed to have adequate storability and post-storage vigor. A tissue damage threshold of 25% was chosen for ease of measurement. There are other operational tests available such as the electrolytic conductivity and the electrical impedance methods (Glerum 1985).

In British Columbia, W. Vidaver of Simon Fraser University is using the variable fluorescence technique of seedling quality assessment. This is a nondestructive method, and indications are that it will be operational shortly. The fluorescence assays have shown a close correlation with other tests now in use, and there are high hopes for this system.

The decision to lift may also be influenced to some extent by the logistical problems of handling such a large amount of stock over a very short period of time. Research carried out by Daniels (1978) indicates that checks on the moisture status carried out during storage do not clearly indicate the true moisture status of the stock; therefore, the moisture status of all stock types should be checked prior to lifting to ensure that no moisture stress exists. Bare-root stock is mechanically lifted into bins by tractor-drawn Fobro lifters and are watered down before being put into the cold storage holding rooms to await sorting. Containers are often lifted during the winter. During freezing conditions, greenhouse temperatures are maintained at 1-2°C; at this temperature, the stock remains winter-hardy and can be still lifted. Under-bench heating is an advantage under those conditions. If the blocks are frozen, they are brought into heated greenhouses so that the plugs thaw enough to be extracted.

Both the container and bare-root stock are sorted to meet set standards and are then bundled according to species and type of stock. The bare-root bundles are usually tied at the root collar with a poly-film, and the container plugs are wrapped in it. All bare-root stock is root trimmed and is often misted while being packed. Both types of stock are then placed in appropriate-sized cartons that are lined with poly-lined kraft bags. The amounts per carton vary with stock type and size. Cartons are then stapled shut and put on pallets for storage. Pallets normally hold 16 cartons.

Pallets are then moved into either cold or freezer storage units, depending on the storage requirements of the stock. The pallets are placed on racks to improve air circulation and the efficiency of the storage unit. Originally, most stock in British Columbia was stored at above-freezing temperatures; however, with the program expansion it has become necessary to freeze a large amount of stock to increase the length of the planting season and to decrease pathogenic storage problems.

Storage temperatures vary depending on the species and stock type. Every attempt is made to get the stock down to appropriate temperatures as soon as possible. Storage temperatures above freezing are in the 1-2°C range, whereas the freezing temperature in the middle of the bundles is -2°C. To achieve these temperatures it is necessary to set the thermostats a few degrees lower, until the correct bundle temperatures are reached. As the rate of respiration is governed by temperature and is doubled or tripled with every 10°C rise (Hardenburg et al. 1986), it is logical to get the stock to its particular storage temperature as soon as is reasonably possible. No mention has been made of humidity during storage because the humidity of a sealed poly-lined kraft bag remains constant. No humidity controls have therefore been designed in the present cold storage systems; however, the relative humidity should be at least 90-95% in the closed bag.

The species being grown and stored are:

Alpine fir (*Abies lasiocarpa*)
Amabilis fir (*Abies amabilis*)
Black spruce (*Picea mariana*)
Douglas-fir, coast and blue (*Pseudotsuga menziesii*)
Engelmann spruce (*Picea engelmanni*)
Grand fir (*Abies grandis*)
Lodgepole pine (*Pinus contorta*)
Mountain hemlock (*Tsuga mertensiana*)
Noble fir (*Abies procera*)
Ponderosa pine (*Pinus ponderosa*)
Sitka spruce (*Picea sitchensis*)
Shore pine (*Pinus contorta*)
Western hemlock (*Tsuga heter ophylla*)
Western larch (*Larix occidentalis*)
Western red cedar (*Thuja plicata*)
White spruce (*Picea glauca*)
Yellow cedar (*Chamaecyparis nootkatensis*)

All the interior stock species are normally put in frozen storage. These include the interior spruces, lodgepole pine, interior Douglas-fir, some *Abies*, red cedar, and larch. The coastal species are not normally frozen, but exceptions are made when there are storage mold or root rot problems. On these occasions, coast Douglas-fir, western hemlock, mountain hemlock, amabilis fir, and shore pine may be frozen to -2°C. Western red cedar and noble fir have also been stored successfully at that temperature; however, as a result of recent problems the storage and handling program is likely to be reviewed. Sitka spruce and the other *Abies* are not normally frozen, although at times they have been.

There are some difficulties in getting stock frozen quickly, because, as mentioned, many of the storage units were designed for storing seedlings at above-freezing temperatures. With the rapid expansion and increased demand for frozen stock, considerable pressure has been put on the cold storage units. This has resulted in an increase in the storage capacity of provincial government and private units, and in some cases refrigeration units have been replaced to meet the demand.

To keep up with the demand for storage space at the nurseries, stock has to be moved out continually during the lifting season. Seedlings are shipped out in both commercial and government refrigerated trailers to either provincial, company, or private cold-storage units. When stock is moved, it must be at the appropriate temperature for the new storage; otherwise, frozen and unfrozen stock in the same unit may cause problems, and this is unsatisfactory when stock is stored for long periods.

Quality control inspections are carried out on either a weekly or biweekly basis to check for any seedling problems and to ensure that the correct temperatures are being maintained. It is essential that the area administrator is informed if stock is starting to develop storage molds or other pathogenic problems. Most areas have an annual training course for cold storage personnel to keep them informed of the latest developments.

Cold-storage personnel are advised by the districts when the various seed lots will be required. It is essential at this phase of the program that sufficient lead time be provided so that stock can be conditioned for outplanting. This is especially important when handling frozen stock, because it takes much longer to thaw containers than bare-root stock (Fig. 1). At this stage these two stock types should be in separate storage units, otherwise one will be ready weeks ahead of the other. One will be actively growing or the other will still be frozen and not conditioned for planting, despite the temperature being turned up.

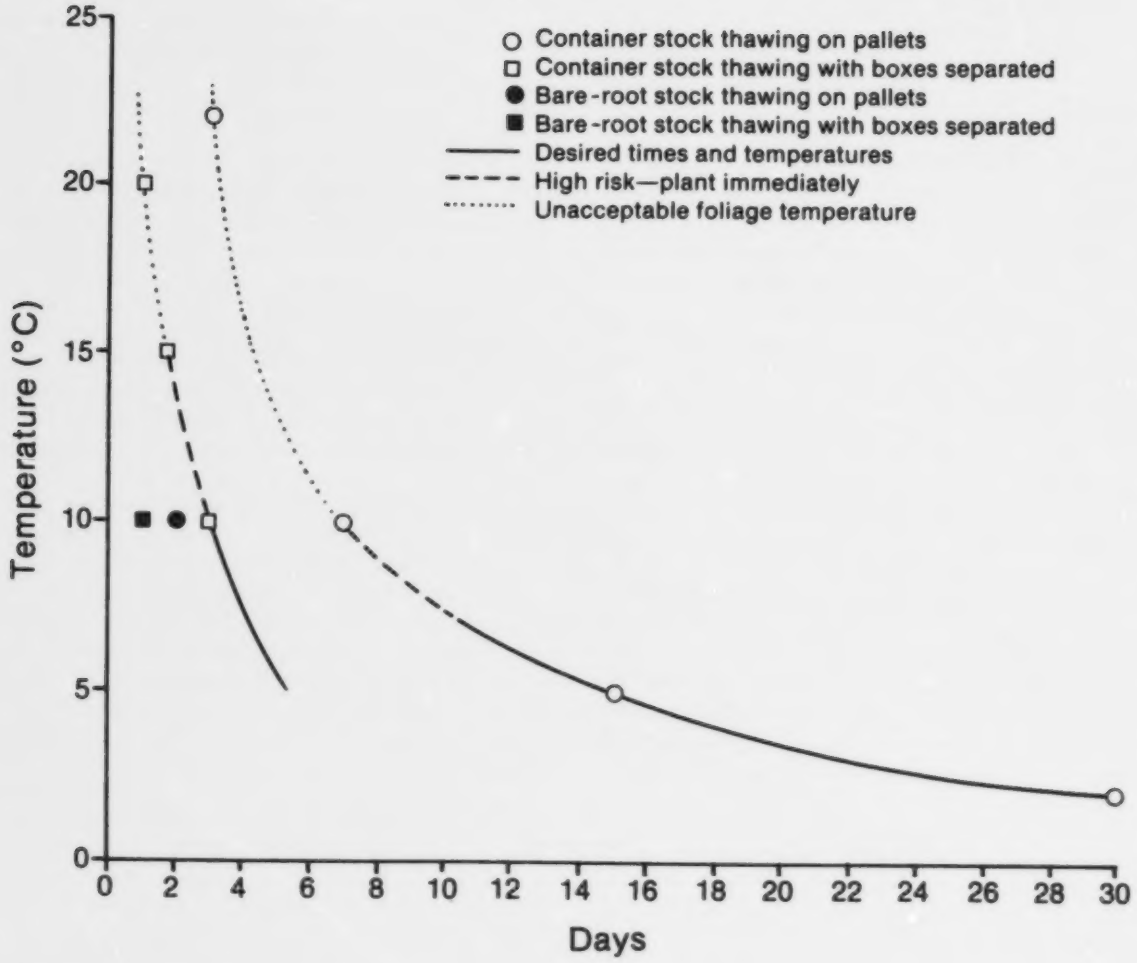

Figure 1. Thawing stock.

Some regions move stock to the districts, where it is stored in storage units or local curling rinks. Conditioning is sometimes done by the manipulation and spacing of the pallets and cartons. Every effort is made to minimize the time between storage and actual planting. On-site storage varies according to the accessibility to cold storage units and may consist of dugouts, caches of various types, and portable reefers. The main consideration is the reduction of planting shock to the seedlings.

THE SUMMER AND FALL LIFT AND COLD STORAGE PROGRAMS

These programs mainly involve the 2 + 0 container stock. As mentioned earlier, there are about 60 million seedlings planted during the summer. Because a considerable amount of stock is being hot planted over extensive areas, some form of cooling is essential if the stock is to be successfully established on the planting sites.

The container blocks are thoroughly irrigated the day prior to lifting. The blocks are then moved to the lifting area, extracted, bundled, and plug wrapped in the same manner as in the winter lift. At this time of year the air temperature is often above 25°C in the shade, and the plug temperature is around 18°C.

The packed cartons are placed on pallets with air circulation spaces between them, in some form of cold storage or in the shade, prior to being loaded into a refrigerated trailer. The loading of stock must be carefully carried out using air spaces and meat boards to ensure that good air circulation exists. Most trailers are capable only of holding the temperature, not of cooling the product. Stock must therefore be precooled prior to shipping.

There are some variations in the packaging of container stock, depending on the nursery, the type of stock handled, and special instructions from the region involved. In some cases short kraft bags that just reach the top of the carton are used. It is often necessary to put a cardboard strip in the bottom of the carton for additional support when the stock is very wet or is to travel on rough roads. Occasionally, stock is packed upright, which often results in the cartons having to be left open. The stock is often over 23 cm tall, and thus when it is shipped in open cartons the refrigerated trailer can only load one layer.

Because the seedlings are actively growing at this time of year, the rate of transpiration must be minimized to reduce the loss of water. There may also be some loss of carbon due to respiration. The rate of transpiration may be reduced by raising the relative humidity, lowering the temperature, reducing air movement, and using some form of protective packaging (Hardenburg et al. 1986). The optimum relative humidity for conifer seedlings is at least 90-95%. At identical relative humidities the loss of moisture is far faster at a high temperature than at a low one. Water vapor, like other gases, moves from a region of high concentration to one of low concentration. Seedlings that are held below their optimum relative humidity will therefore release water vapor into the atmosphere. The drier the conditions, the more rapid the loss of water. When there are differences between the surrounding and internal vapor pressures, transpiration or evaporation will continue. The difference in the vapor pressure is called a pressure deficit. The loss of moisture is usually highest during the first few hours or days in storage, when the stock is being cooled. The longer it takes to lower the temperature of a product to the

storage temperature, the greater the moisture loss will be.

As noted before, the rate of respiration is governed by temperature, and for every 10°C rise in temperature the rate is roughly doubled. The faster a plant respires, the greater is the quantity of heat that is generated. It therefore becomes necessary to reduce the temperature of the stock as soon as possible.

Every attempt is made to get the summer-lifted stock to the planting sites as soon as possible. As mentioned for the winter lift program, a great many seedlings are grown in the southern areas of the province. This means that it is often 5-6 days from the time of lifting seedlings to planting them. Some form of cold storage therefore becomes essential, when transpiration and respiration are considered.

In provincial nurseries, summer-lifted stock are placed in cold-storage units, which are run at about 5°C. This drops the carton temperature to about 10°C in 24 hours. As none of the storage units have been designed for high humidity, misting is sometimes carried out when the stock is being held over for a few days.

SOME GENERAL COMMENTS ABOUT COLD STORAGE

Plastic returnable crates are soon going to be used on an operational basis in British Columbia. This will allow upright packaging and will improve the air circulation and reduce carton damage during transportation. It is hoped that the returnable crates will help to reduce the costs. This type of crate may be used in high-humidity storage units; however, winter-stored stock will have to be sealed in the poly-lined kraft bags. When transpiration and respiration are considered, a review of the stock handling and shipping during the summer lift will probably have to be made.

During the June and July lift, millions of bare-root seedlings were shipped to and transplanted at various nurseries around the province. This stock was lifted, sorted, bundled, root pruned, packaged in roll-sealed kraft bags, placed in cartons, cooled, and then shipped. There did not appear to have been any problems as long as the seedlings were transplanted within 7 days. After that there were problems, with the percentage of mortality increasing as the days from lifting to transplanting increased.

The Ministry of Forests has used filo-cell high-humidity storage for winter storage, but the high humidity had a detrimental effect on the wax-impregnated cartons during long-term storage. Perhaps wax-dipped cartons or the plastic crates would have worked.

There is a new, small, pressure-cooling cold-storage unit being used by the vegetable industry. This unit is capable of reducing the core temperature of packaged cartons or crates of produce from 25°C to 1°C in 3 hours and could possibly reduce the temperature in the bundle of summer- shipped forest seedlings to 7°C in 1 hour. The air moving through the crates has a relative humidity of around 98%. This type of unit might be suitable for the summer stock shipment. As it reduces the loss of water from the plants and the rate of respiration, stock quality might be improved. It could perhaps be utilized in the holding rooms where the winter bare-root stock is held in bins prior to sorting. These are the same rooms often used for cooling stock in the summer lift.

The lettuce industry vacuum cooler was tried out some years ago. It has the ability to drop the temperature from 25°C to 1°C in 20 minutes; however, if used without free water it

dehydrates the plants. Although the seedlings survived, it is not a practical method of cooling forest seedlings.

Tilhill Nursery near Farnham in England has two types of cold storage; jacketed cold storage and the quick-chill, ice-bank, humi-cold systems. The jacketed system was extremely expensive to build and was not as effective as the humi-cold one. In fact, Tilhill has just built another humi-cold unit of 650 m^2. This type of unit allows bare-root stock to be stored in large, open crates with no sacking or any protection around the roots. Cold, moist air is passed continually over the stock. The unit runs at 1°C with a relative humidity of 97% and has a complete absence of free moisture. Conifer seedlings are packed in bin-sized crates and stored up to 6 months in these units. The original unit has been operating successfully for about 10 years.

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STORAGE OF NURSERY STOCK

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INTRODUCTION

Refrigerated storage of nursery stock has been used at the Shelterbelt Centre's tree nursery since the late 1960s. Large-scale storage was made possible with the construction of a cold storage facility in 1979. Over two million seedlings are currently placed in storage each fall.

Indoor storage of nursery stock has proven extremely beneficial to tree nursery operations. As the Shelterbelt Centre distributes seedlings over a wide geographical area, some regions are ready to plant trees before the nursery can begin spring lifting. With the use of cold storage, shipping schedules can be adjusted to suit local planting conditions. Similarly, cold storage can provide a buffer for meeting shipping quotas when bad weather delays spring operations. If desired, surplus planting stock of some species can be held over until fall or the following spring.

Cold storage has provided direct benefits to production operations. During fall lifting, seedlings can be stockpiled in cold storage prior to culling and sorting, should bad weather delay operations. In spring, seedlings brought in from heeling-in plots can be kept dormant until shipping is complete. Cold storage provides for an accurate inventory system, and seedlings can be routinely monitored for quality during the storage period. Cold storage reduces winter losses to rodents and frost damage that may occur in the field or heeled-in storage. Properly lifted, handled, and stored, deciduous seedlings survive and grow as well as spring-lifted or heeled-in stock, and in some cases quality is better, especially if spring lifting conditions are not optimum.

Over the past 20 years, numerous studies evaluating storage requirements have been conducted at the Shelterbelt Centre. Early studies concentrated on establishing the value of and need for indoor storage, but as expertise and confidence in freezer storage increased, specific projects concerning seedling maturity, temperature, packing methods, and disease control evolved. To date, storage specifications for 18 deciduous and four coniferous species produced at the tree nursery have been established. The result of these studies has been the development of a storage program that ensures efficient overwinter storage of seedlings with minimal loss in quality. The most significant outcome of the early research was the construction of a fully modern cold storage facility in 1979. This paper presents an overview of storage studies carried out at the tree nursery from 1963 to 1987 and provides recommendations based on these studies for refrigerated storage of nursery stock.

LIFTING AND CONDITION OF SEEDLINGS

It is well known that for best results lifting should be scheduled when seedlings are dormant or, in the case of deciduous species, vegetatively mature. It was generally accepted by early researchers that deciduous plants are fully mature when defoliation is complete. Several

studies at Indian Head have supported this theory. Various dates for lifting caragana, green ash, Manitoba maple, and Siberian elm have been evaluated. Results indicate that outplanting survival increased with date of harvest for all species except green ash, which was not affected (green ash had defoliated prior to the first harvest date). Best survival occurred for seedlings that had defoliated prior to lifting. Based on these studies, early recommendations were that harvesting should be delayed until defoliation is complete.

Unfortunately, some deciduous species such as Siberian elm, poplar, and willow retain leaves into the late fall, which delays lifting operations. To overcome this problem, studies were conducted to evaluate the effects of mechanical or chemical defoliation of seedlings prior to lifting. Several chemicals that efficiently remove foliage have been identified.

In summary, lifting of deciduous species should be delayed until leaf abscission (which usually follows several killing frosts). Species that naturally drop their leaves late in the fall (Siberian elm, willow, poplar, and villosa lilac) can be defoliated with chemicals such as endothal and ethrel. The removal of foliage from seedlings is essential for successful storage, because this process removes the potential inoculum and substrate for subsequent mold growth.

Seedling maturity is of even greater importance for coniferous species. The quality and storability of seedlings is greatly influenced by the lifting date. Studies have indicated species differences in the onset of dormancy. At Indian Head, white spruce and Colorado spruce are ready for lifting in early October, whereas lifting of Scots pine should be delayed until late October (Fig. 1). Because the lifting process is such a critical stage in the storage of conifers, considerable attention has been focused on this area. Over the years numerous techniques ranging from dormancy induction to monitoring of the physiological status of seedlings have been evaluated. The Shelterbelt Centre is currently assessing seedling maturity by monitoring root growth and then developing root growth curves.

MATERIALS FOR WRAPPING AND PACKING ROOTS

Following lifting, it is essential that seedlings be quickly transported to the storage site. Early studies indicated that even though seedlings are dormant, every precaution should be taken to prevent desiccation of the roots. Successful storage depends on the maintenance of high humidity (95-100%) within the storage room. Maintaining high humidity is difficult when seedlings are stored with roots exposed to the air. Studies at Indian Head have shown that seedlings are damaged when humidity falls below 85%.

Various methods of maintaining high humidity and preventing desiccation have been investigated at Indian Head. Storage in sealed polyethylene bags consistently produced the best results, whereas covering seedlings with moist peat moss had no effect when seedlings were stored in polyethylene bags.

STORAGE TEMPERATURE

Over the years, two main storage temperatures, -2°C and 1°C, have been evaluated at Indian Head. Other temperatures periodically evaluated were -5°C and -18°C. Storage at 1°C consistently resulted in the superior performance of most species when compared to other temperatures. Storage at -5°C, although inferior to 1°C, had no deleterious effect on seedling quality, whereas -18°C storage severely damaged most species.

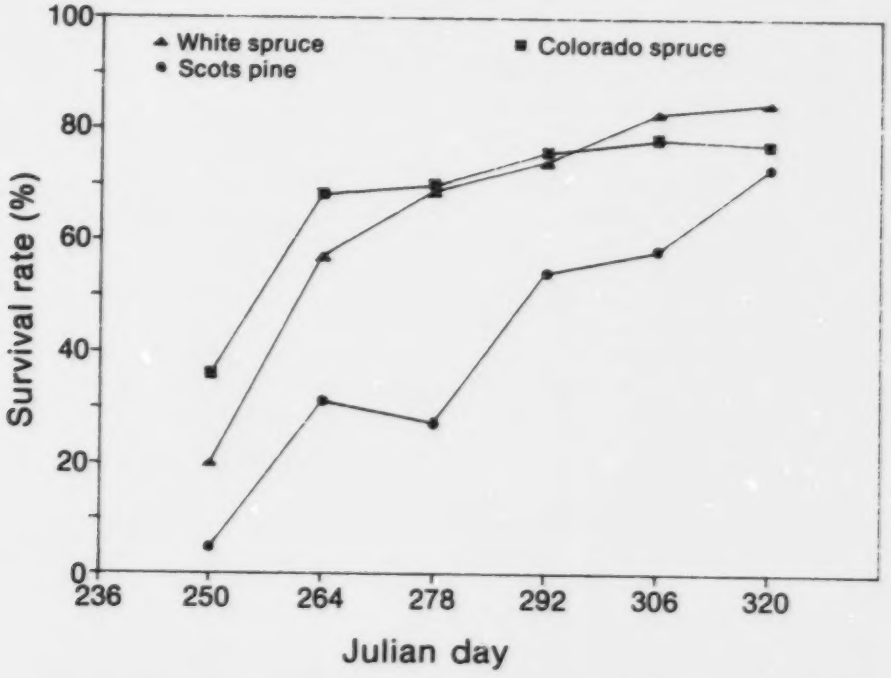

Figure 1. Survival rates of three conifer species lifted on six dates and stored over winter.

Preconditioning seedlings at 5°C for several weeks prior to storage at 1°C or -2°C is not beneficial. Results indicate that seedling temperature should be brought down to 1°C as quickly as possible following lifting. After a period of 1-2 weeks at 1°C, seedlings can be further cooled to subfreezing (-2°C) temperatures if required.

Under most conditions, storage at 1°C was recommended. If mold was a potential problem, storage at subfreezing temperatures (-2°C) was more appropriate, but at -2°C there is a greater chance of desiccation, so appropriate preventative measures should be taken.

The effect of removing seedlings from storage in midwinter has been evaluated. Removing seedlings from storage over winter is sometimes necessary when sorting or mold control is required. Results of these studies indicate that the quality of seedlings was reduced with the length of time out of storage, and a critical exposure period of 7 hours was established.

STORAGE MOLDS

Molding of stem and root tissue can cause severe losses during storage and can result in poor survival and first-year growth. Molding is dependent on the presence of dead and damaged tissues and on the physiological state of the seedling. Most mold fungi cannot infect healthy tissue; consequently, good harvesting techniques are essential. High storage temperatures also promote molding; however, a critical temperature level has not been determined.

To date, molding has not been a serious problem during storage. Most instances of mold damage have been

related to the fluctuating temperatures coupled with the presence of foliage on deciduous seedlings or of damaged tissue on conifers. Certain deciduous species such as poplar, willow, red elder, Siberian elm, and lilac are susceptible to molding because of foliage retention, whereas Colorado spruce is the principal conifer species affected. Maintaining subfreezing temperatures (-2°C), removing foliage prior to storage, and careful handling during harvest are the major factors in the prevention of mold buildup. Seedlings are monitored during the storage period, and mold development is recorded.

Pre- and post-harvest fungicide (Benomyl) treatments have been evaluated for control of mold during refrigrated storage. Both treatments were equally effective mold inhibitors in this particular study. Recent studies, however, have questioned the value of these treatments.

CONIFEROUS STORAGE RESEARCH

Since 1981, emphasis has been on the development of storage techniques for coniferous species, particularly Scots pine. Conifers are characteristically more difficult to store than deciduous seedlings. This has been attributed to the complex dormancy process in conifers. Stored conifers often fail to break bud, or bud break is delayed until late in the growing season.

Studies have concentrated on identifying the optimum storage temperature for Colorado spruce, white spruce, and Scots pine. Results of this work indicate that white spruce and Colorado spruce should be stored at -2°C, and Scots pine should be stored at 1°C (Fig. 2).

In addition to storage temperature, the effects of packing materials, ethylene, and preconditioning treatments on the storability of Scots pine have been investigated. Basic physiological studies on carbohydrate reserves and respiration during the storage period are also under way.

In 1985, a storage study comparing the storability and tolerance of new Scots pine strains to freezing storage temperatures was initiated. Results indicate that the storability of the Siberian strain of Scots pine was superior to other strains (Fig. 3). In addition, the Siberian strain tolerated storage at -2°C with no loss in quality.

RECOMMENDATIONS AND FUTURE RESEARCH

Based on studies conducted at Indian Head, successful storage is dependent upon the following factors:

1. Maturity at time of lifting--Seedlings must have reached vegetative maturity to satisfactorily withstand refrigerated storage. Lifting should be delayed until natural leaf drop. If this is not possible, chemical or mechanical defoliation is necessary. Conifer lifting should be delayed until October (late October for Scots pine).

2. Retention of seedling moisture--After lifting, seedlings should be immediately cooled and desiccation minimized during the sorting and grading period. For maximum humidity retention, seedlings are packed in polyethylene bags.

3. Storage temperature--An initial storage temperature of 1°C is recommended. It is important that seedlings reach this temperature as soon as possible after lifting. After 2-3 weeks the storage temperature can be lowered to -2°C except for Scots pine, which should not be stored below 0°C (lowering of temperatures is required if mold problems are anticipated). Accurate temperature monitoring within

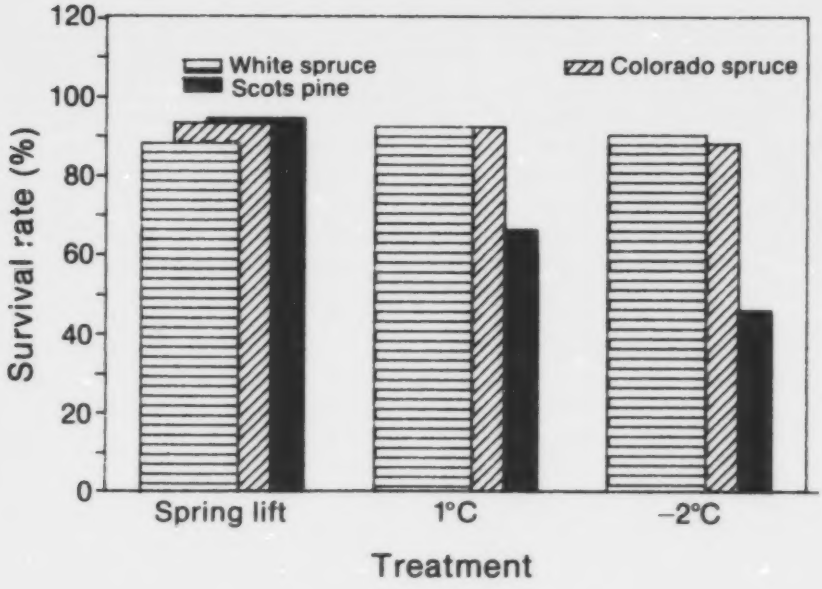

Figure 2. Survival rates of three conifer species spring-lifted or stored over winter at 1°C and -2°C.

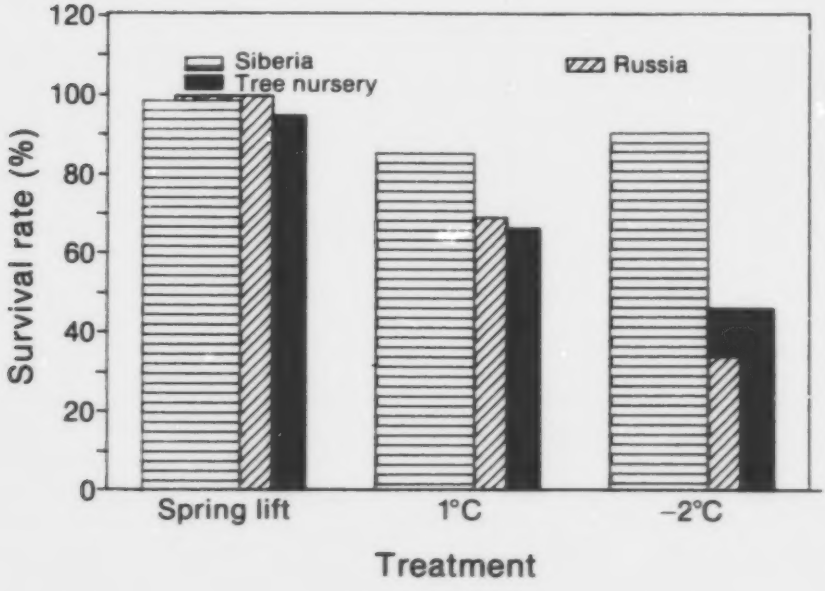

Figure 3. Survival rates of three Scots pine seed sources spring-lifted or stored over winter at 1°C and -2°C.

the cold storage area is a necessity. If seedlings have to be removed from storage during the winter, exposure to warm temperatures should not exceed 7 hours.

4. Prevention of mold--Under certain circumstances (nondormant stock, tissue damage), seedlings may develop mold during storage. Keeping the temperature at a constant and subfreezing level and proper seedling handling practices are the most effective methods of suppressing storage mold development.

5. Good seedling handling--If possible, lifting should be carried out during dry conditions. Seedlings should be protected at all times and roots kept moist. Air temperatures in the packing shed should be cool during sorting and culling. All damaged, weak, diseased, and undersized stock should be culled and seedlings packed loosely in polyethylene bags so that there is some free air space.

COLD STORAGE PROCEDURES AND FACILITIES AT BIG RIVER FOREST NURSERY

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Our new packing plant and cold storage facility was completed last spring just prior to spring lifting. The cold storage area consists of three separate, independently controlled rooms, each complete with a fixed racking system. The three areas combined give us cold storage capacity for approximately 5 million seedlings. Twelve condensing units and evaporators provide cooling for the refrigerated storage areas.

Nine temperature probes are located throughout the cold storage areas. They are hooked into a central recorder located outside the refrigerated storage area that constantly scans the probes and produces a digital readout of probe temperatures. This recording device can also be programmed to print out probe readings at anywhere from 0.25-minute to 240-minute intervals.

Our pallets each hold 16 tightly stacked seedling boxes. These seedling boxes measure 12 x 18 x 24 inches. Each rack compartment holds 12 pallets, three deep by four high.

Air spaces are maintained on all sides of each pallet; however, boxes within the pallet are tightly stacked and there is no allowance for air movement.

Our smallest cold storage room is used as a precooler to lower seedling temperatures before packing and sorting. Tubs of freshly lifted trees are held in this refrigerated room until they are required on the grading tables. Temperature controls are usually set at about 1°C. During hot weather this helps to bring initial high seedling temperatures down slightly before packing. Seedling roots were moistened during packing if they appeared dry.

This spring, several temperature settings were tried during cold storage. Early in the lift, temperature controls were set at approximately -2°C. This allowed for room temperatures approaching -4°C. At this temperature, inside boxes on our pallets required about 5 days to reach 0°C, although outside boxes were below 0°C. As the lift progressed during hot weather this spring, root and bud activity of the incoming stock prompted us to raise the temperature settings of the coolers to approximately 1.5°C to keep the seedlings above the freezing point within the boxes. On particularly hot days, the temperatures of some stored seedlings, packed during the heat of the day, rose for several days before beginning to cool down, and more than a week was required to bring inside box temperatures down to 1-2°C. All stock performed well in monitoring plots at both temperatures, although seedlings were not held for a long period of time before planting.

This spring, only 2.5 million seedlings were lifted and cold stored in a facility designed to hold double this amount. This allowed us the luxury of only partially filling our racks. The upper racks, which begin at about 16 feet above the floor, were not utilized. Inexperienced forklift operators were able to work on the lower three rows, which was a blessing! Forklift alleyway clearances are a bit tight for easy access to the racks, and pallet alignment on the

racks was considerably easier when the upper row was not used.

We are by no means experts at cold storage, as this is the first year we have had a storage facility. Previously, our stock was cooled down after being packed in a 40-foot reefer van and trucked to the Prince Albert nursery for cold storage. It will be interesting to compare notes with others on their storage procedures, temperatures, and problems. We have never tried overwintering stock in cold storage, although a late lift of jack pine will be tried out this fall.

COLD STORAGE FACILITIES, PRACTICES, AND PROBLEMS AT PINE RIDGE FOREST NURSERY

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Smoky Lake, Alberta

PHYSICAL DESCRIPTION

- Four bays or cool rooms, designed to hold seedlings at -2.2°C.

- Capacity of the bays is 17 136 boxes; the capacity of the alleyways is 7704 boxes.

CONSTRUCTION

- Cinder-block walls with 4-inch rigid insulation. Ceiling is plywood with 6 inches of rigid insulation. There are 4 inches of rigid insulation under the concrete slab. Outside the cinder-block walls there is a layer of strapping to hold the cedar siding.

SORTING AND PACKING

- The standard box used to date is 750 mm long, 229 mm high, and 400 mm wide (30 × 16 × 9 inches) and is wax impregnated.

- We will be changing to a new box that is 610 mm long, 355 mm high, and 355 mm wide (24 × 14 × 14 inches). The new box has the following advantages: no strapping is required; there is less cardboard to act as insulation around seedlings; it is cheaper; the trees are sorted 20 to a bundle with an elastic band; trees are packed inside a 6-mil plastic bag so that the box is full but not packed too tightly; the roots are packed to the ends and the tops to the middle; the roots only are watered with a wand-type waterer; boxes are strapped and loaded 18 to a pallet; 1/2-inch spacers (wood slats) are placed between each pallet layer; and the pallet is taken immediately to cold storage.

LOADING

- Loading is done with a Raymond Model 31F30TT forklift with short turning radius.

- Seedlots are packed progressively in the cool rooms until each one is full, and then the aisles are filled if necessary.

COOLING AND FREEZE-DOWN

- Unit temperatures are set initially at -5°C until the monitoring equipment indicates that internal box temperatures are -1°C to -1.5°C on outside boxes on the pallets. Temperatures are then set at -2°C to prevent excessive cooling below -2° or -3°C.

- Monitoring is done until all trees are frozen; controls are manipulated as required to ensure freeze-down.

- Once all trees are frozen, controls are set at -2°C and left for the winter. Daily monitoring continues.

MONITORING

- Each cool room has four temperature probes that lead to a Fluke Model 2240C data logger.

- A printout is obtained every 2 hours showing the temperature in the box that the probe is in.

- Probes are strategically placed to cover many different locations (i.e., outside box on pallet, inside box on pallet, top of bay, mid-bay, bottom of bay, in different species (spruce or pine), near middle of a box, or on outside of a box.

- Physical inspection is done each day to record probe temperature, air temperature, and the general condition of coolers.

- A thermometer is hung inside each cooler to measure air temperature. This is recorded during daily inspection.

- An additional Micrologger (Lakewood Systems Ltd. Model LE 8110-8K) with 8-channel capacity can be installed in one cooler, and an intensive study of one pallet can be conducted.

TESTING

- Commencing in late January, selected seedlots are sampled and R.G.P. testing is done on each seedlot in January, April, May, and June (if seedlings are not shipped).

- R.G.P. testing will show if deterioration of any seedlot is occurring due to plants using up their carbohydrate reserves. It also shows the condition of a seedlot at packing time.

SHIPPING

- Loading is done no more than 12 hours ahead of shipping.

- Trees are placed inside well-insulated reefer vans, and temperatures are maintained at -2°C until a minimum of 24 hours before planting, at which time they are thawed under space tarps.

PROBLEMS

- In some instances, poor performance of seedlings is making us look at our freeze-down regimes, as it can take up to 52 days for all seedlings to freeze. We suspect that this is too long.

- Storage mold is also a problem in some of our stored seedlings. The mold is active between the time of lifting and packing and the time of actual freeze-down. If we can shorten this time we should be able to just about eliminate storage mold incidences.

- We are currently having a literature search conducted to see if we can take trees to -5°C or lower without damage. This would mean a shorter overall freeze-down period.

- We will be consulting with a refrigeration engineer this winter to see if the cooling capacity can equal the number of calories that the trees are required to lose to cool them to -2°C within 3-4 weeks.

- The PFRA Shelterbelt Centre's testing for R.G.P. shows that there is a rapid decrease in seedling root growth potential after 28-30 weeks of storage. In order to avoid this, every effort is being made to plant PRFA's bare-root stock as early as possible in May the following year.

COLD STORAGE FACILITIES, PRACTICES, AND PROBLEMS

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The Alberta Tree Nursery ships bare-root deciduous and coniferous plant material to the farmers of Alberta. Since 1980, the average shipment has been 2.5 million trees per year. This is a brief account of the facilities and methods used to overwinter plant material for spring shipping.

THE FACILITIES

Three types of overwinter storage are used at the tree nursery: freezer storage at -2°C, cold storage at +4°C, and heeling-in grounds.

Freezer Storage--Headerhouse Cooler

This is a new facility at the tree nursery, first used at full capacity for shipping in 1985. The cooler is underground beneath a one-storey headerhouse. Access is by forklift only, via a ramp. Capacity is for three million seedlings, and 346 m^2 is limited to pallets stored three high. A 10-hp compressor runs one large evaporator, and a 12-hp compressor runs six small evaporators. Either system can maintain freezing temperatures. The system runs primarily at -2°C, ranging from -2°C to -5°C, which allows for defrosting of evaporators. Relative humidity is maintained at 82-96%.

The temperatures are stabilized before graded stock is brought in and are maintained until one month prior to shipping start up. At this time the temperature is raised to 4°C to allow for handling of the stock.

Cold Storage--Cooler II

This facility is attached to the packing shed--shipping area. It is an aboveground cinder-block structure. The capacity is five million seedlings in a 480 m^2 area with pallets stored five high. It has two 20-hp compressors, each powering three evaporators. The system runs from 1°C to 5°C; 70-85% humidity is maintained manually.

Heeling-in Grounds

We use one of several fields close to the packing shed. Our soil tends to be wet and heavy, which causes problems in both placing and removing stock.

PRACTICES

The present practice is to lift all deciduous stock starting the last week of September. Plants that are above 60 cm are cut back in the field using a forage harvester or side-arm mower. The material is lifted in order of natural leaf drop, e.g., poplars and green ash are first, and willows and common lilac are last. Cooler II is used for holding storage.

Grading is started one week after lifting, and material is processed in the order it is lifted. If leaf drop did not occur in the field, leaves are manually stripped from the plants during grading.

For freezer storage, the graded material is placed in 1-m^3 pallets. The material is placed with roots to

the side of the pallet and stems overlapping stems. The top layer of roots is covered with peat moss and the pallet is covered with 2-mil clear plastic. The pallets are taken to the headerhouse cooler on a daily basis. The capacity of the freezing unit and the good insulating effect of the underground structure are such that the input of plant material does not cause a rise in the cooler temperature. The pallets are placed in rows 15 cm apart; the spacing between rows allows for better heat exchange, hence freezing.

The material to be heeled-in (those species of higher volume, e.g., caragana and Brooks #6 poplar) is lifted and graded early. The plant material is loaded onto trucks instead of being palletized. A one-way plow is used to make both the furrow and backfill after the plants are placed.

Some material for shipping is from Spencer-Lemaire containers. This material is taken from the lathhouse and graded after the field stock is processed. Weather is not a limiting factor with this material. Cooler II is an excellent storage facility for this material.

PROBLEMS

To date, coniferous material has been fall harvested on a trial basis in limited numbers only. It was sorted in the same fashion as deciduous stock. In our plantings, 92 of 100 Colorado spruce and 95 of 100 white spruce survived the following year. This compares favorably with spring-lifted material. Poor harvest weather prevented a fall harvest in 1986.

During each shipping season a bundle of seedlings of each species and from each storage method are set aside to plant out after shipping is complete. Over the past 3 years the freezer storage has proven superior. The appearance of the plant material at shipping time shows that freezer-storing plant material has eliminated the problems of mold encountered both in the heeling-in grounds and at 4°C. The amount of leafing-out of material before shipping is completed is also greatly reduced.

One species that is currently a large problem is field-grown bur oak, regardless of the storage type tried. Damage to the tap root, mold in non-freezing storage and heeling-in grounds, and its inability to break dormancy on planting out all contribute to its poor performance. We are currently trying bur oak as a 1-year greenhouse-grown seedling for shipping.

Russian olive, silver buffaloberry, and sea buckthorn have also given less than satisfactory results, independent of storage conditions. *Prunus* material used in our conservation bundle has alternated from year to year, with one species a problem one year and a different species the following year.

Given these variables, we feel confident in the storage conditions themselves and have come to conclude that the real problem lies in the timing of the harvest and quick, efficient handling of the material once harvested.

PINELAND PROVINCIAL FOREST NURSERY PRODUCTION SUMMARY

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Pineland Provincial Forest Nursery
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The 1987 season was a busy one at Pineland, as bare-root and container programs were running at near capacity. It was also a year for construction, with the official opening of a new tree improvement facility funded jointly by the provincial and federal governments and the construction of a new cold storage-packing shed facility.

CONTAINER PROGRAM

In January, 2.4 million seedlings were sown. This crop was moved to the shade frames in May, and shipping was completed by the end of July. The second crop of 2.9 million seedlings was sown in June; 1.7 million of these were grown for transplanting in August or next spring. Stock that was transplanted in August received 10 days of short-day treatment to initiate budset prior to transplanting. In addition to multipot 1s and 2s, trees were also grown in Plastique Gagnon containers and paperpot trays.

Problems last year from high-light intensity in the greenhouses have been alleviated by covering greenhouses with shade cloth during hot, sunny weather and by using silica grit instead of black poultry grit.

BARE-ROOT PROGRAM

In October 1986, 4.1 million jack pine and red pine were sown, and another 1.5 million Scots pine, red pine, and black spruce were sown in May and June, 1987. Sixty-two percent of the seeds were drilled and 38% were broadcast.

In April, 6.8 million seedlings were lifted. Sorting and packing took place at Pineland, but the majority of seedlings had to be stored in Winnipeg in rented cooler space and shipped directly from Winnipeg. A small percentage of the seedlings were stored in refrigerated vans on site. With the completion of the new cold storage facility in September, this process will be greatly simplified.

This season was the second year that the nursery has undertaken a major transplanting operation; 1.3 million seedlings were transplanted in April and May and another 3.4 million were transplanted in July and August using an eight-row mechanical transplanter.

Our present inventory is as follows: 1 + 0, 5.4 million; 2 + 0, 4.2 million; transplants, 4.5 million; ship stock (1988), 11.0 million.

SEED PROGRAM

The summer of 1986 saw a very poor spruce cone crop. Only 2.4 hL of cones were brought in, and 1.8 kg of seed were cleaned. A total of 700 hL of black spruce, Scots pine, and jack pine cones were received, and 492 kg of seed were cleaned between September 1986 and June 1987. There was a good spruce crop this summer, and over 530 hL of cones were collected in July and August. A cone rake was used for the first time for cone collection.

TOWNER STATE NURSERY

R. Laframboise
Towner State Nursery
Towner, North Dakota

1987 TREE SALES

Tree sales from the North Dakota Forest Services's Towner State Nursery totaled 1 068 718 in 1987, which was down slightly from the 1 268 145 in 1986.

This total comprises 908 628 conifers and 160 090 hardwoods. A total of 30 species are grown at Towner; blue spruce, Scots pine, and ponderosa pine are the largest sellers. The trees are used for shelterbelt, farmstead, and wildlife plantings in North Dakota and surrounding states.

CONTAINER PRODUCTION

A 30 x 100 foot greenhouse is used to grow seedlings under controlled environment conditions. The seedlings are grown in 30-cubic inch containers in a mixture of peat and vermiculite. One crop of 40 000 seedlings is grown per year starting March 1 and ending August 15.

The major species grown in the greenhouse include bur oak, blue spruce, Scots pine, ponderosa pine, Siberian larch, black hills spruce, and hackberry.

NURSERY PRODUCTION AND MAINTENANCE REPORT

D. Gruber
PFRA Shelterbelt Centre
Indian Head, Saskatchewan

HARVEST OPERATIONS

Harvest operations began on September 24 and were completed on November 5. A total of 5 834 405 deciduous and coniferous seedlings were lifted, sorted, counted, and stored. Of this total, 2 033 945 deciduous seedlings were stored in 388 bins in cold storage, and the remaining 3 745 550 were stored in the heeling-in plot. There were 42 000 Colorado spruce and 12 910 white spruce harvested, counted, placed into poly-lined bins, and stored in cold storage. No Scots pine were placed in cold storage. The remaining 408 000 Colorado spruce, 44 090 white spruce, and 171 600 Scots pine were lifted during the packing and shipping operations. An average of 220 651 seedlings were sorted and counted per day during fall harvest.

PACKING AND SHIPPING OPERATIONS

The packing of prepacked and special orders began on April 8. This was done by full-time staff and four casual workers. Bulk shipments began on April 13 and were completed on May 7. A total of 6 195 035 deciduous and coniferous seedlings were distributed to 9874 applicants in 44 156 bales.

CONIFER TRANSPLANTING OPERATIONS

Transplanting operations began on May 11 and were completed on May 21. There were estimated totals of 540 000 Colorado spruce, 240 000 Scots pine, and 180 000 white spruce planted this spring. There were two part-days of downtime due to windy, hot conditions. After planting, each plot was irrigated for a short period of time. The seedlings were then packed between the rows, sprayed with Linuron (70 oz. per acre bulk) in 63 gallons of water per acre, and irrigated for 2-3 hours, depending on the moisture content of the soil.

PLANTING OF HARDWOOD POPLAR AND WILLOW CUTTINGS

Planting of hardwood poplar and willow cuttings began on May 7 and was completed on May 25. There were estimated totals of 692 000 poplar (northwest, Walker, Assiniboine, and mixed poplar) and 812 120 willow (acute, laurel, silverleaf, Chermisina, and mixed willow) planted.

After planting, the cuttings were packed and sprayed with Linuron 45% flowable at 70 oz. in 54 gallons of water per acre. The fields were irrigated immediately after spraying. This operation required a crew of 14 to operate two four-row planters and two tractors. Approximately 200 000 cuttings were planted per day.

DECIDUOUS FIELD SOWINGS

Caragana sowings began on June 15 and were completed on June 24. There were nine fields or 26.8 acres sown at a 32-inch row spacing, and two fields or 5.2 acres were sown into beds. These sowings required 1983 pounds of seed. Caragana sowings were sprayed with chloroxuron (Tenoran) 50% WP at 10 pounds per acre (bulk) in 54 gallons of water per acre. The fields were irrigated with up to 1 inch of water immediately after sowing and spraying.

There were 100 feet of American elm and 100 feet of Japanese elm sown into four rows on June 25. The remainder of the field was sown to Siberian elm. Trifluralin (Treflan) 54.5% EC at 30 ounces per acre (bulk) in 54 gallons of water per acre was applied and incorporated to a depth of 2-3 inches 7 days prior to sowing. The field was irrigated immediately after sowing.

Ash (16.9 acres), Manitoba maple (2.6 acres), and lilac (16.2 acres) will be sown in October. Manitoba maple is grown as a 1-0 crop. All 1-0 deciduous fields are sprayed with Linuron 45% flowable at 70 ounces per acre (bulk) in 60 gallons of water per acre in the late fall. On a trial basis this fall, one-half of a field will be sown to caragana beds. The remainder of this field will be sown to beds in the spring. Two fields of ash will also be sown on a trial basis.

Oats, grass, and field peas were sown in early June. A field of fall rye was sown the last week of August.

SHRUB BED AND FIELD SOWINGS

On June 8, one-half bed of bur oak was sown. On July 13 one-half bed of snowberry and hawthorn was sown. The remaining shrubs will be sown on various dates from the first week in September through to the middle of October. There were 1.2 acres of shrubs sown into fumigated beds. Shrub beds are fumigated by incorporating Basamid 98% granular at 312 pounds active ingredient per acre in moist soil approximately one month prior to sowing. Incorporation should be to a depth of 3 inches. The bed should be packed lightly and approximately ¼-inch of overhead irrigation applied. The soil surface should be kept moist for 3-5 days following Basamid application. At the completion of sowing, silica sand is spread on the beds approximately ¼-inch deep. Irrigation is applied if soil conditions are dry.

CONIFER SEEDBED PRODUCTION

Conifer seedbeds are sown in the spring and fall. Colorado spruce, Siberian larch, and Scots pine are sown in May. As a result of studies by the Investigations Section, it has been recommended that Scots pine be sown during the second week in June. This should help reduce the size of the Scots pine seedlings. White spruce is sown in the middle of October. The beds are fumigated in the fall, and sideboards are erected in preparation for spring sowing. Conifers are grown in seedbeds for 2 years (2-0) before being lifted and planted into the transplant plots. Harvesting of the 2-0 conifers usually begins around the 15th of October, but the Investigations Section usually advises as to when the seedlings are ready for lifting. Approximately 1.2 million seedlings are lifted and stored in cold storage. The seedlings are removed and sorted for poor color and root damage in March and are then returned to cold storage until they are planted in May.

EQUIPMENT FABRICATION

Some equipment fabricated at the nursery this past year included a fruit depulper; a 16-foot conveyor belt; sprayer "U" booms; a 4 x 7 foot conveyor belt; 10 shelterbelt planters; and a trailer for the all-terrain vehicle. A conveyer belt for spring packing was modified.

PRINCE ALBERT FOREST NURSERY--1987 OPERATIONS

J. Chernysh
Prince Albert Forest Nursery
Prince Albert, Saskatchewan

BARE-ROOT OPERATION

The lifting operation started on April 21 and was completed on May 6. For the peak period, an additional 40 casuals were hired; we returned to a regular staff of 42 afterward.

The following seedlings were lifted this spring:

3-0 white spruce	2 330 180
4-0 white spruce	149 125
Scots pine	17 250
Total	2 496 555

STOCK DISTRIBUTION

A total of 2 345 000 white spruce and 373 368 IPL-container jack pine were shipped to northern reforestation projects. The Scots pine were shipped to regional parks, schools, or woodlots.

NURSERY PRODUCTION

The seedling production target for this spring was 7 000 000 white spruce to be shipped as 3-0 stock.

Immediately following seeding, fields are normally treated with a covering of hydro mulch. This year two fields were left untreated. To date, after visual inspection, seedling performance in those two fields does not look different from that in the treated fields. We will continue to monitor them during the crop rotation.

The wet July and August seemed to cause a significant weed problem in all fields, portulaca being the weed of most concern. This was suppressed by spraying infected fields with 40 gallons of Varsol per acre. Only the very young plants were killed. Larger ones were slowed down enough to give weeders a chance to remove the weeds. No other chemical was used on this growing stock this year. A soils study was done this summer under a Forest Resource Development Agreement contract paid by Forestry Canada. It was determined there was a phosphorus deficiency, and the recommendation was to apply 225 kg per acre of 11-51-0 fertilizer.

In the fall seedbed preparation, this amount was applied along with 500 kg per acre of sulfur and 135 kg per acre of Basamid during the first week of September.

CONTAINER PRODUCTION

One crop was seeded this year. Seeding started on May 11 in IPL trays.

	No. trays	No. trees
Jack pine	10 333	692 311
Lodgepole pine	1 122	75 174
Scots pine	365	24 455
Total	11 820	791 940

A container crop of approximately 350 000 white spruce was held over from 1986 and will probably be planted in the spring of 1988. All stock overwintered with good results.

SEED EXTRACTION

During the fall of 1986, 175.48 hL of jack pine cones were collected,

producing 88.050 kg of seed. This fall there was a quota to purchase a total of 1775 hL of white spruce cones from the various seed zones. There are 1200 hL of jack pine cones tentatively to be collected by Weyerhaeuser Canada Limited and processed in our plant.

DECIDUOUS PRODUCTION

A total of 187 876 deciduous trees were shipped for planting in the southern part of the province, and 68 400 poplar and 14 950 willow cuttings were included.

OTHER PROJECTS

We are looking into a dust collection system for the headerhouse, and we may improve the present dust collection system in the packing shed.

The new pumphouse is completed, but there are some deficiencies in its operation that must be corrected. The pH sensor was incorrectly mounted, but that has been corrected. It now appears that the acid pump cannot supply enough acid to change the pH significantly. All other systems, when programmed properly, work as specified in the design.

OPERATIONS AT BIG RIVER FOREST NURSERY--1987

J. McCutcheon
Big River Forest Nursery
Big River, Saskatchewan

A total of 2 562 800 seedlings were lifted and shipped from Big River Nursery this spring. The total consisted of 1 836 400 white spruce (3-0); 600 300 jack pine (2-0); 126 100 jack pine (3-0).

Lifting began on April 20 and was completed on May 9. The growing season was abnormally cool and wet after hot and dry conditions in May and June.

PROBLEMS ENCOUNTERED THIS SEASON

1. Damaging frosts hit our rising 2-0 and 3-0 seedlings in mid-May, causing considerable damage to flushing seedlings.

2. A severe infestation of seedling poplar and willow invaded our fields of rising 1-0 seedbeds this year. We were unable to control all of them by hand, so three fields of 1-0 white spruce were sprayed with Roundup at 0.5 pounds per acre active ingredient. Good control was achieved.

3. Marsh crane fly larval damage was significant again this year on rising 2-0 white spruce. Most of the damage was confined to wetter areas on beds bordering irrigation lines, where seedling stems are girdled at or below the ground line. No attempt at control was made.

4. Some damping-off and root rot occurred on rising 1-0 seedlings during early July when constant rain saturated the seedbeds for days on end.

5. A plugged intake line feeding our wet well in the irrigation pumphouse caused some headaches early this spring. The low-level cut-off switch for the reservoir was installed too low, causing both of our irrigation motors to burn out when the pumps began sucking air. Fortunately, we were able to get one of them rewound within several days and were able to limp by until the other was completed a week later. The weather was hot and dry at this time and 1-0 seedlings had just germinated, but suffered no damage.

NEW DEVELOPMENTS

Spring 1987 saw the first operational use of our new packing plant and cold storage facility. The double-stacked conveyor system in the grading room performed well, as the crew had fewer problems adjusting to the new system than we had anticipated.

Some modifications to the original installation of the tree-tub feed ramp had to be made, but once these were accomplished the system worked well.

OPERATIONS AT PINE RIDGE FOREST NURSERY--1986-87

R. Hamilton
Pine Ridge Forest Nursery
Smoky Lake, Alberta

Overall production was somewhat reduced at Pine Ridge in the 1986-87 season due to the completion of the 5-year "Maintaining Our Forest" afforestation program. The emphasis was placed on improving crop production to provide better planting stock and seed for reforestation efforts throughout the province.

CONTAINER PROGRAM

In March 1987, 9.5 million seedlings were sown. In June, 4.7 million seedlings were sown. The seeding line was modified to sow all four sizes (40, 65, 90, and 175 cm^3) of Spencer-Lemaire containers. This year was the first year that all four Spencer-Lemaire containers were sown on a production basis at Pine Ridge. The 40, 65, 90, and 175 cm^3 containers were all sown for all areas in the province for the "Regen Performance Monitoring" program. This program consists of outplanting all available container sizes plus bare-root and plug + 1 seedlings on a variety of site types in all forest locations throughout the province in order to better match site type and tree type for future reforestation efforts. This is a 5-year study, and seedlings are being remeasured each year. Also this year, Pine Ridge extracted 560 000 container seedlings and packed them in boxes in cold storage for spring 1987 planting. By doing this, a fully dormant tree is being planted. Previously, all containers were shipped in the spring from the shade frames, and the containers were either partially or fully active depending on the time of shipping and planting. The dormant tree is less prone to planting shock.

BARE-ROOT PROGRAM

In the fall of 1986, 7.5 million trees were lifted and packed in cold storage for outplanting in the spring of 1987. Current stock is as follows: 7 129 810 of 3-0 (to be lifted fall of 1987), 10 079 849 of 2-0, 7 431 968 of 1-0 (sown spring 1987).

This was the second year that Pine Ridge used its new Summit precision sower. We are quite pleased with the results, as we feel that proper spacing and good bed density will help solve some of our bare-root seedling quality problems. During the lifting and packing operations, a greater emphasis was placed on quality control, and more-stringent culling specifications were set.

A study on current mechanical conditions, insulation, and cooling capacity of our reefer vans was conducted in the summer of 1986. During the winter of 1986-87 a project was initiated at the Alberta Forest Service (AFS) construction and maintenance shops to upgrade all insulation to R24 and to increase and control proper airflow in our fleet of vans. Four vans and five refrigeration units were replaced as part of this program.

In the summer of 1987 we transplanted 1.5 million container seedlings into bare-root fields for lifting and packing in 1988.

SEED PROGRAM

The spruce crop in 1986 was moderate across central Alberta. The AFS and forest companies collected 2566.1

hL of white spruce; 6295.3 hL of lodgepole pine were also picked for processing in the winter of 1986-87. The seed extraction plant ran a single shift in November, December, and January and a double shift in part of February and March to process all the cones on hand. During this time, the following seed was extracted and cleaned for storage: spruce, 2643.2 kg; pine, 1475.7 kg; miscellaneous, 6.2 kg.

The following amounts of seed were withdrawn for direct and nursery sowing from September 1986 to August 31, 1987: spruce, 5711.11 kg; pine, 1770.25 kg; miscellaneous, 133.38 kg.

This year saw the initiation of a province-wide "Seed Improvement Program" presented by Pine Ridge staff to AFS and forest industry staff across the province. Seed from superior stands is to be collected either in bulk from squirrel caches or aerially from select trees and is to be used to improve the quality of nursery stock sowing.

SHIPPING

In the spring of 1987, 7 547 578 bare-root and 4 652 000 container seedlings were shipped. Another 7 million containers will be shipped this fall, for a total of 19.1 million seedlings.

INVESTIGATIONS AND RESEARCH

The 1986-87 season saw a reduction in the number of research projects being initiated at Pine Ridge and more emphasis on monitoring stock quality.

GENETICS AND TREE IMPROVEMENT

Production

Seedlings for various trials such as stock for black spruce and tamarack provenance trials and rootstock for grafting purposes and shelterbelts were reared this past year. Production for a demonstration forest located at Jumping Pound began; it includes native and exotic species arboreta, clonal variations in aspen planting, and two seed-source trials.

Grafting

The largest grafting program to date (over 3000 grafts) was completed for seed orchard and clone bank requirements. This was the first year for grafting black spruce, tamarack, and Siberian larch. The success rate on these was 50% for black spruce and Siberian larch and 90% for tamarack. We are now gearing up for a small Douglas-fir grafting program.

Seed Orchards

One white spruce seedling seed orchard is established on site, and there are two white spruce grafted seed orchards in the developmental stages. Also established is a Ravola larch and a clonal Scots pine seed orchard.

Species Testing

We have initiated a green ash species trial to determine its forestry potential. Siberian larch and Scots pine trials have been established and look very promising.

CHAMPION FOREST PRODUCTS TREE NURSERY OPERATIONS--1987

L. Matwie
Champion Forest Products (Alberta) Ltd.
Hinton, Alberta

The 1987 season saw an increase in crop size and our seed collection program.

SEEDLING PRODUCTION

A total of 2.4 million container seedlings were grown in 1987. Of this total, 1 650 000 were planted in the current year. The remaining stock will be overwintered for spring planting in 1988.

A total of 725 000 seedlings survived overwintering in 1986-87. An unusually high mortality rate of 29% appears to have been caused by air movement within the cold frames and abnormally warm temperatures, which desiccated the seedlings.

SEED COLLECTION

Cone collection was very successful. A total of 1280 hL of lodgepole pine cones were collected, with an anticipated yield of 260 kg of seed. This will raise our total seed inventory to 1200 kg in anticipation of several large aerial seeding programs in 1989-90.

EXPERIMENTS IN PROGRESS AT THE PFRA SHELTERBELT CENTRE, INDIAN HEAD, SASKATCHEWAN

1. SIBERIAN LARCH NUTRITION/SEEDBED DENSITY

Objective: to determine optimum sowing density and nitrogen levels for production of 2-0 Siberian larch.

Treatments: three seedling densities and three fertilizer levels were evaluated. Fertilizer treatments were applied as split applications, one in early July and one in mid-August.

	Nitrogen fertilizer (kg/ha)		
Density	0	20	40
Nonthinned	NT.0	NT.20	NT.40
2 cm	2.0	2.20	2.40
4 cm	4.0	4.20	4.40

2. DATE OF SOWING SCOTS PINE SEED

Scots pine seedlings grown for 2 years in seedbeds are often too large for efficient mechanical transplanting. In an attempt to reduce the size of seedlings grown in the seedbed, it was proposed that Scots pine be sown in late spring or early summer.

In the spring of 1985 a study was initiated in which Scots pine was sown at standard rates in production seedbeds on three dates. The sowing dates were mid-May (conventional sowing date), mid-June, and mid-July.

The number of usable seedlings per metre for years 1 and 2 and heights for year 2 are shown below:

Sowing date	Usable seedlings/metre Year 1	Year 2	Year 2 height (cm)
Mid-May	176	132 c	11.9 c
Mid-June	128	94 b	8.5 b
Mid-July	84	21 a	6.0 a

The number of usable seedlings per metre in the second year was somewhat reduced from the first year, but results were consistent in that the mid-May sowing was superior to the later sowings.

Seedling height may, therefore, be reduced by approximately 30% by postponing sowings of Scots pine until mid-June, but the number of usable seedlings will likely be reduced proportionately.

3. PRODUCTION OF 3-0 SCOTS PINE

Production of Scots pine at the Shelterbelt Centre is a very labor-intensive operation. Present practice is to grow seedlings in seedbeds for two growing seasons, transplant, and grow for 2 more years prior to lifting for distribution. The seedlings lifted from the seedbed are generally too large for efficient mechanical transplanting. It was thus proposed that seed be sown directly to beds in production transplant plots and lifted after three growing seasons.

In 1985 a study was initiated to investigate the feasibility of producing 3-0 Scots pine. Scots pine was sown at standard rates to nursery transplant plots. Plots were hand-

thinned to three densities, and three fertilizer treatments were evaluated as shown below:

Ammonium sulfate (21-0-0)	Density
0 kg/ha N	2.0 cm
10 kg/ha N	4.0 cm
20 kg/ha N	8.0 cm

The fertilizer rates were broadcast on plots in early July and mid-August each year. Seedlings will be lifted in the fall of 1987, and top and root growth, caliper, root growth capacity, and outplanting survival will be evaluated.

4. SCOTS PINE TREE IMPROVEMENT PROGRAM

The objective of Scots pine tree improvement is to develop a tree with a vigorous, upright growth habit, superior crown density, dark green foliage color, and good needle retention for farmstead and field shelterbelts on the prairies. The improvement program includes provenance trials, progeny tests, and controlled matings as well as grafting and importation of seed from its natural range.

In 1962 a provenance test that included 28 Soviet Union seed sources was established at the Shelterbelt Centre. Twenty-year data for this planting indicated that several seed sources from three specific regions of the USSR and Siberia were superior to standard Shelterbelt Centre sources.

The progeny from 20 seed sources from the 1962 provenance test were field planted in south-central Saskatchewan. After 5 years, trees from the same regions as mentioned above were the most vigorous.

In 1983, each tree in the provenance planting was rated for desirable characteristics. Twenty-four superior phenotypes were selected as the breeding population for the development of an improved strain of Scots pine. Controlled breeding of seven superior trees was done in 1983 and 1986, and full-sib progeny from these matings will be used to design a clonal seed orchard.

Three half-sib regional tests have been established in northwest, northeast, and south-central Saskatchewan using progeny from the same seven selected seed trees. The objective is to evaluate the performance of Scots pine under field shelterbelt conditions in different areas of the prairies. Based on these performance evaluations, the family heritability of specific traits will be determined for each seed tree, and parents will be selected from seed orchards and future breeding programs.

5. 1987 HERBICIDE TEST FOR POPLAR CUTTINGS

Herbicides tested: oxyfluorfen (Goal), linuron (Lorox L), and chloroxuron (Tenoran).

Time and method of application: applied overall May 12, 1 week after planting, then irrigated.

Weed control results:

Treatment	Rate (kg/ha)	Weed counts: Walker poplar June	Walker poplar July	Assiniboine poplar June	Assiniboine poplar July
1. check weeded	-	-	-	-	-
2. check not weeded	-	400	14	90	9
3. oxyfluorfen	0.5	13	6	2	4
4. oxyfluorfen	1.0	1	2	0	1
5. linuron	1.75	7	6	2	3
6. linuron	2.25	3	2	1	3
7. chloroxuron	5.5	18	3	7	4

6. 1987 HERBICIDE TEST FOR WILLOW CUTTINGS

Herbicides tested: oxyfluorfen (Goal), linuron (Lorox L), and chloroxuron (Tenoran).

Time and method of application: applied overall May 21, 6 days after planting, then irrigated.

Weed control results:

Treatment	Rate (kg/ha)	Weed counts: Acute and Chermisina willow June	Acute and Chermisina willow July	Laurel and silverleaf willow June	Laurel and silverleaf willow July
1. check weeded	-	-	-	-	-
2. check not weeded	-	58	4	50	4
3. oxyfluorfen	0.5	0	1	1	2
4. oxyfluorfen	1.0	0	0	0	0
5. linuron	1.75	2	2	0	3
6. linuron	2.25	0	1	0	0
7. chloroxuron	5.5	3	2	3	1

7. 1987 SETHOXYDIM TEST FOR CONIFER TRANSPLANTS

Species tested: Colorado spruce, white spruce, and Scots pine.

Treatment	Rate (kg/ha)	Time and method of application
1. check weeded	-	No treatment
2. check not weeded	-	No treatment
3. sethoxydim	0.15	Apply as an overall spray when
4. sethoxydim	0.18	annual grasses are in the 2-5
5. sethoxydim	0.8	leaf stage

8. 1987 HERBICIDE TEST FOR CONIFER SOWING

Herbicides tested: oxyfluorfen (Goal), lactofen (Cobra), and ethalfluralin (Edge).

Time and method of application: applied as an overall spray, preemergence to crop and weeds.

Weed control results:

Treatment	Rate (kg/ha)	Weed counts		
		Colorado spruce		Scots pine
		June	July	(July)
1. check weeded	-	-	-	-
2. check not weeded	-	122	12	20
3. oxyfluorfen	0.25	27	7	1
4. oxyfluorfen	0.50	14	6	2
5. oxyfluorfen	0.75	17	5	1
6. lactofen	0.4	16	4	4
7. lactofen	0.8	21	4	1
8. lactofen	1.2	8	4	1
9. ethalfluralin	1.0	48	16	2
10. ethalfluralin	2.0	10	5	1
11. ethalfluralin	3.0	7	9	1

9. FUNGICIDE TIMING TRIAL TO PREVENT MOLD ON 2-3 COLORADO SPRUCE

Objective: to determine if mold can be prevented during storage with a preharvest fungicide treatment.

Treatments:

Treatment	Days applied prior to harvest	Mold rating (0-4)	Percent survival
A. Benomyl	7	1.25	100
B. Benomyl	1	1.25	100
C. Captan	7	1.25	89
D. Captan	1	1.25	98
E. Thiram	7	1.00	99
F. Thiram	1	1.25	100
G. Vinclozolin	7	1.25	89
H. Vinclozolin	1	1.00	100
I. untreated check	-	1.25	100

10. PRESTORAGE FUNGICIDE DIP TRIAL ON WALKER POPLAR CUTTINGS

Objective: to determine the most effective prestorage treatment to prevent storage mold and increase field survival.

Treatments:

Treatment	Mold rating (0-4)
A. Vinclozolin	1.00
B. Benomyl	2.50
C. Captan	2.00
D. Dodine	3.00
E. Thiram	1.00
F. Ferbam	1.25
G. water dip check	2.00
H. check (nondipped)	2.25

11. CUTTINGS CULTURE

a. Position of Cutting on Poplar Whips

In a preliminary study done in 1985, results indicated that cuttings taken from the base of whips had better emergence, survival, and growth than cuttings taken from the middle and tip of whips.

In 1986 cuttings were made from whips of Walker poplar and northwest poplar, keeping terminal, middle, and basal cuttings separate. Both greenhouse planting and field planting studies were done on each species.

Initial results indicate better growth, survival, rooting, and rate of emergence with cuttings taken from the base of the whip. Further evaluations are to be completed in the fall of 1987.

b. Quality of Walker Poplar Stools

Some stooling beds at the Shelterbelt Centre have been in use for 14 years. Past studies have recommended that stools be removed every 5 or 6 years and replaced with new ones. In 1986 a study was initiated to determine whether the age or quality of stooling beds affects survival and growth of cuttings planted to production fields.

The results of the greenhouse test indicated that older stools (planted in 1973) were as good as stools planted in 1978 and 1982 as far as growth, rooting, and survival were concerned but that fewer usable whips and cuttings were available from older stools.

c. Stimulation of Adventitious Shoots in Walker Poplar Stools

A study was initiated in 1987 in an attempt to increase the number of whips on Walker poplar stools. Some stools were topped after 50-60 cm of new growth in the spring of 1987. Other stools were topped a second time after another 25-30 cm of new growth, and nontopped stools were included as a check.

All topping was detrimental to the growth of the stools, and the second topping especially showed severe chlorosis, whereas nontopped stools looked healthy and had excessive growth.

d. Production of Poplar Mini-cuttings

If a procedure could be developed to plant mini-cuttings using a mechanical 'seeder', considerable time and labor could be saved in production of poplar rooted cuttings. As well, more rooted cuttings could be produced from a single whip using this method.

In a preliminary study initiated in the spring of 1985, small 5 cm and 8 cm cuttings were broadcast over a seedbed and rototilled into the soil.

Almost 50% of these cuttings rooted, even though some were sitting on top of the soil surface.

In 1987, 8-cm mini-cuttings of four poplar clones were planted in a single furrow row at a depth of approximately 2.5 cm using a nursery tree planter. Emergence and survival as of June 30 was 46% overall.

ATTENDEES AT THE 1987 PRAIRIE FEDERAL-PROVINCIAL NURSERYMEN'S MEETING

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